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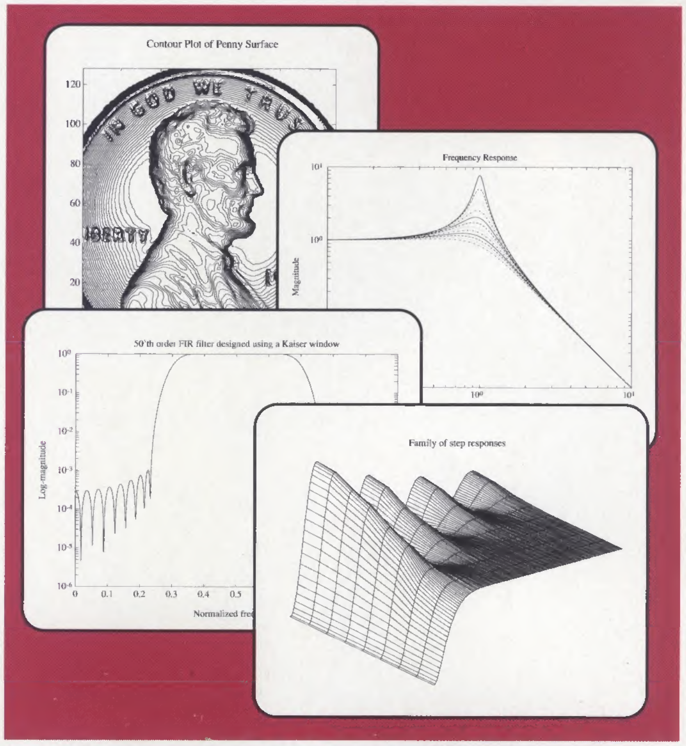

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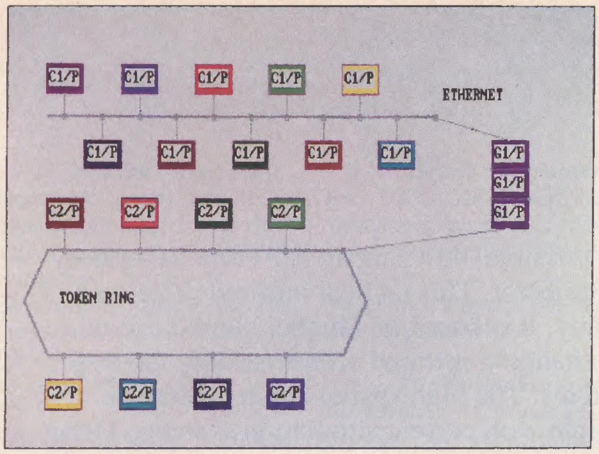

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SCIENCE/SCOPE®

A new and better way of testing missile target seekers is possible, now that an Air Force laboratory simulation system will use an advanced infrared image projector. This tactical infrared projection system (TIPS) was developed by Hughes Aircraft Company. It is based on Hughes' liquid crystal light valve technology. TIPS projects TV-like images of changing infrared scenes, testing the target detection and tracking performance of seeker sensor systems. The high spatial and temperature resolution of these images provides capabilities not possible with current simulation systems. Using laboratory simulations rather than launching test missiles to test target seekers is expected to save the Air Force considerable money.

Hughes technology protected the lives of civilian and military personnel in the Persian Gulf. Hughes' products included: infrared focal plane arrays used in defense systems for detecting Scud missile launches, fire suppression systems in the Army's M1 tanks and Bradley fighting vehicles, and target detection devices in precision missiles used by coalition forces. Hughes now intends to expand its diversification efforts, developing these and other state-of-the-art technologies for new, commercial markets.

Germany has upgraded portions of its air traffic control systems with a new state-of-the-art system built by Hughes. These TracView systems give air traffic controllers a real-time, full-color digitized display of aircraft detected by multiple radars that feed into air towers and centers. Installed in former West and East German sites, TracView provides automated identification and beacon code correlation and networked beacon code allocation. The systems draw sensor data from a wide range of old and new radars built by Western and Eastern Bloc companies.

The Navy's "Top Gun" Training System will have a new level of realism and value, now that Hughes is producing a digital computer to link it with the F-14's Hughes-built radar. The computer link will improve real-time interface for F-14 aircraft used in this "Top Gun" Tactical Aircrew Combat Training System (TACTS). The system allows pilots to fly air combat missions against one another without ever firing a shot, as ground instructors monitor their moves in real time, from any angle, on large multicolor computer graphic displays.

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Newslog

NOV 15. **Toshiba Corp.,** Tokyo, announced a joint venture to manufacture electric and electronic components in China with **Hangzhou Machinery and Electronic Development.** The joint venture—set up because of a labor shortage in Japan—will be based in Hangzhou.

NOV 18. Germany's **Siemens AG** and Japan's **Toshiba Corp.** said they had agreed to develop and market reduced-instruction-set computing (RISC) microprocessors based on technology from **MIPS Computer Systems Inc.,** Sunnyvale, Calif. Areas that could be jointly developed are MIPS' R3000 and R4000 series of RISC processors and the supply of RISC silicon wafers to each other.

NOV 18. **AT&T Co.** announced that early in the new year it will offer frame relay service, a form of data transmission nearly 30 times as fast as current methods. Although several AT&T competitors have already announced frame relay offerings for the new year, AT&T's size will sharply expand the service's availability.

NOV 18. **Compuadd Corp.,** Austin, Texas, and **Sysorex Information Systems,** Falls Church, Va., said they had been awarded a US $1 billion, three-year computer contract to supply the U.S. Department of Defense with up to 300 000 desktop computers based on Intel Corp.'s 286, i386, and i486 microprocessors.

NOV 19. **Philips Electronics NV,** Eindhoven, the Netherlands, said it is joining forces with **SGS-Thomson Microelectronics BV,** Gentilly, France, to develop advanced logic chips at a new French research facility in Crolles. The joint effort—their first commercially—will focus on the design of logic chips that contain circuits with submicrometer line widths.

NOV 20. **Texas Instruments Inc.,** Dallas, and **Hitachi Ltd.,** Tokyo, said they would combine efforts over the next 10 years to design and develop 64M-bit dynamic RAM chips for sale in the mid- to late-1990s.

NOV 21. The **Federal Communications Commission (FCC),** Washington, D.C., approved broad new pricing policies that will allow U.S. corporate telephone customers to pick and choose among an array of new telecommunications network features—rather than being required to buy a variety of bundled services, including unneeded ones—from Bell regional companies. The FCC also eliminated the requirement that Bell companies set up separate subsidiaries to offer information services.

NOV 24. The space shuttle **Atlantis** was launched from Cape Canaveral, Fla., with six astronauts and a military surveillance satellite on board. As the first unclassified launching of an Air Force satellite, it should trim millions of dollars off security costs, officials said. The mission included testing how useful a soldier in space might be in providing tactical information to ground commanders.

NOV 25. The **Japanese** began the world's first regular full-scale high-definition television broadcasting (HDTV) on the date that matches the 1125 lines on a Japanese HDTV screen. With the airing of 8-hour broadcasts of its Hi-Vision system—an analog version of HDTV developed over two decades by a broadcasting group led by **NHK, Japan's national broadcaster**—the country became the first nation to bring HDTV to prime time. However, at US $30 000 a set, the advanced TVs needed to receive Hi-Vision are found only in hotel lobbies and big public buildings.

NOV 25. Germany's **Siemens AG** announced a US $170 million venture with Czechoslovakia's **Skoda Plzen AS** and **Skoda Praha AS** to offer fossil-fired and nuclear power plants, hydroelectric generators, and environmental management systems. Skoda is the energy division of Czechoslovakia's largest engineering group.

NOV 26. **Motorola Inc.,** Schaumburg, Ill., said it has launched a new type of microcontroller chip that incorporates a flash electrically erasable programmable ROM (EEPROM). The new chip, which permits stored data or a program to be updated electrically in-system, reduces the number of external components and allows changes to be made late in the production cycle or even after.

NOV 26. **U.S. Trade Representative Carla A. Hills** said she would begin the legal process for restricting some imports from **China** in retaliation for the failure of U.S.-Chinese trade negotiators to agree to stop the piracy of U.S. patents, copyrights, and trademarks. It is the first time the United States has sought trade sanctions because another country did not protect U.S. inventions.

NOV 26. A Federal District Court judge issued an injunction that indefinitely bars **Energy Secretary James D. Watkins** from opening the first U.S. permanent repository for nuclear wastes at the US $1 billion **Waste Isolation Pilot Plant** in Carlsbad, N.M. The action came six weeks after New Mexico was joined by Texas and four environmental groups in a lawsuit that said Watkins violated Federal law by seeking to open the repository without congressional approval.

NOV 26. **IBM Corp.** announced plans to reshape its worldwide operations by splitting up into an organization of loosely affiliated subsidiaries more responsive to the demands of the marketplace. The company said the restructuring will reduce its workforce by 20 000 over the next 12 months and save about US $1 billion in 1992.

NOV 27. The **U.S. Congress** approved and sent to President Bush a bill that would ban the use of automated dialing devices that deliver recorded messages to the home without prior consent (they can reach 20 million Americans on any given day). The bill would also prohibit autodialers from sending junk faxes to more than two business lines at one time.

DEC 2. **NCR Corp.,** Dayton, Ohio, which was bought by AT&T Co. in September, said it had agreed to acquire **Teradata Corp.,** El Segundo, Calif., a computer company that specializes in parallel processing, for US $520 million in stock. With Teradata, NCR said it would broaden the use of parallel processing into high-performance general-purpose computing.

DEC 4. **Pan American World Airways** shut down its operations, two days after Delta Airlines ended a financing arrangement that would have enabled Pan Am to run a Latin American airline service from Miami. It was the third U.S. airline to stop flying this year—after **Eastern Airlines** in January and the regional **Midway Airlines** in November.

Preview:

JAN 31. By this date, **McDonnell Douglas Corp.,** St. Louis, Mo., intends to conclude its agreement with **Taiwan Aerospace Corp.,** Taipei, on the sale of up to 40 percent of its jetliner business for US $2 billion. The accord—plus requisite government approvals—will lead to the formation of a new jetliner company that will include several other Asian manufacturers.

COORDINATOR: Sally Cahur

JANUARY 1992 Volume 29 Number 1

IEEE SPECTRUM

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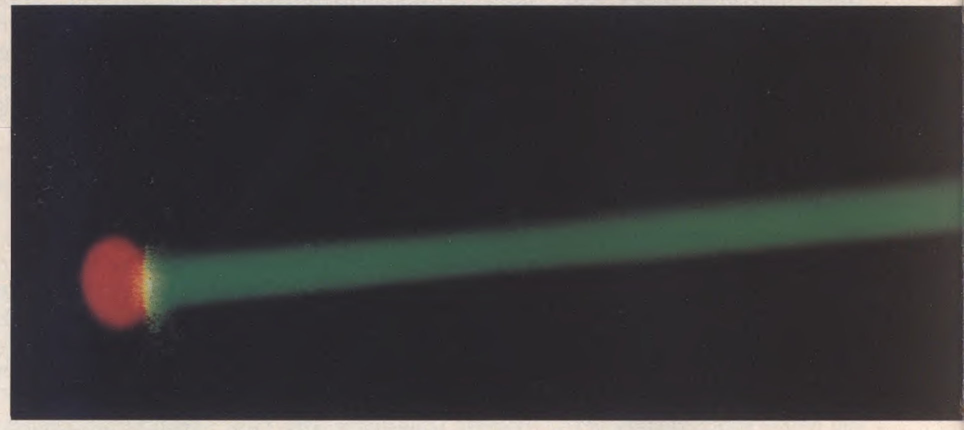
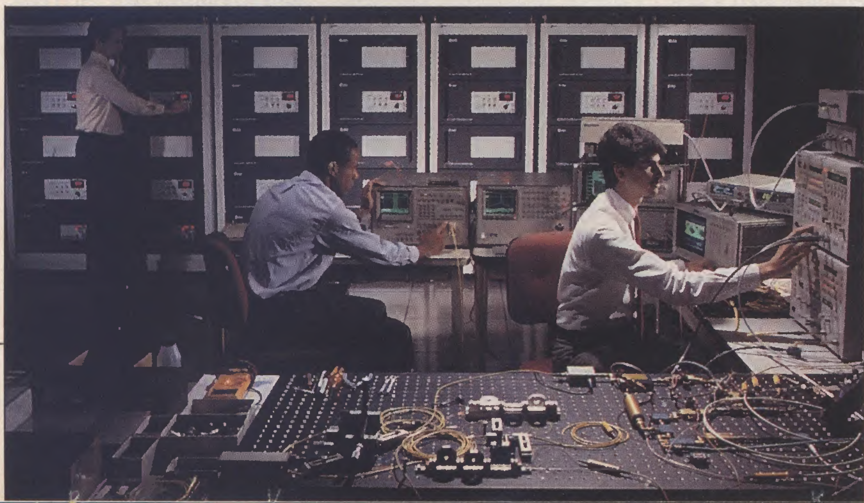


Even silicon emits light: a highly porous silicon layer glows red under illumination by a green laser beam. Potential applications include flat-panel displays and telecommunications. 42

AT&T Bell Labs engineers demonstrate error-free transmission of lightwave signals at 10 gigabits per second over 2000 km of optical fiber. 36



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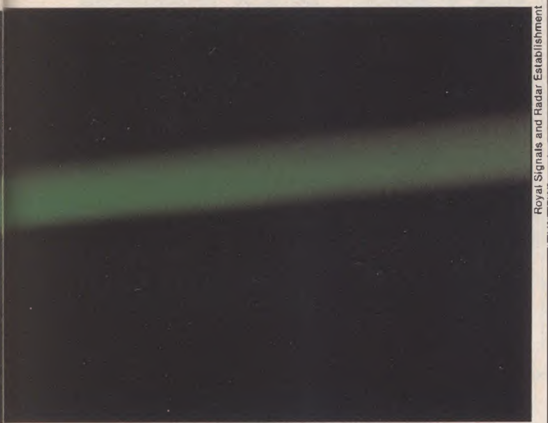
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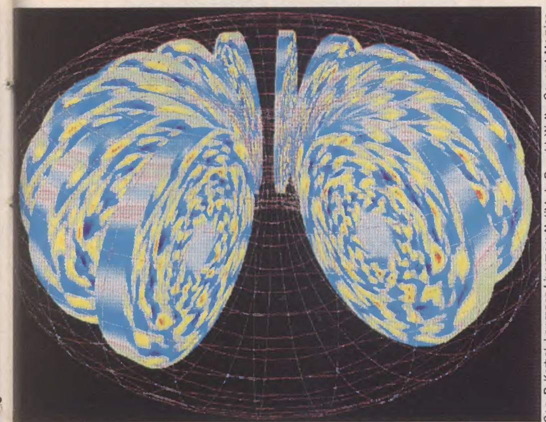
Gary D. Kerbel, Lawrence Livermore Nat'l Lab; Ronald Waltz, General Atomics

Shown are electric potential contours for tokamak plasma turbulence rendered on a CM-2 at Los Alamos using graphics software called Crystal. The red and blue are centers of counterrotating helical vortices. **33**

Cover: This 60-carbon-atom molecule, or buckyball, was imaged on a Cray Y-MP2E computer at the Los Alamos National Laboratory. White, green rods represent single, double bonds. Galaxies in the background are computer generated. See p. 33. Photo: Melvin L. Prueitt, Los Alamos National Laboratory; data supplied by William Harter, University of Arkansas.

SPECTRAL LINES

The ease and speed with which measurements can be made suggests the possibility of instrumentation or measurement overkill. But the trouble is, no one knows for sure just which measurements are unnecessary.

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Reflections

Proprietary information

The Vugraph consisted of a single large word. "INTRODUCTION," it said. In small letters at the bottom of the foil was that ubiquitous warning, "Proprietary information, XYZ Corporation." I glanced around warily. Was there any unauthorized person present who might glimpse that secret word "introduction"? I had a twinge of the feeling I experience when I play a rented videotape and see the "FBI warning" notice that must be endured before the actual movie comes on. I always expect a loud knock on the door, and some tough-looking guy in a trench-coat waiting there to arrest me for some inadvertent but illegal use of the rented tape.

The lawyers are nervous about engineers giving away precious information. They have a point. After all, XYZ Corporation has paid for the thought that went into the generation of the word "introduction." Seeing that word might save a competitor the development expense of coming up with their own word for an opening Vugraph.

What a different story it is at a professional engineering meeting, like an IEEE conference. There we find engineers showing block diagrams and algorithms, and discussing in detail all the reasoning that went into their products. Out of their pride in their technical accomplishments they babble on and on about the details. The speakers will tell you everything they know and then some. Of course, there are no lawyers around to stop them.

In contrast, the intellectual property people have this concept of a virtual great wall that can be drawn around their company, keeping all the inside information in, while allowing all the outside information to diffuse right through to the inside—sort of a lobster trap for information. No golden rule here, and no nonsense about being better to give than receive.

I try to imagine a world where that informational wall is strictly enforced. The IEEE journals and conferences would be banned. Instead, the IEEE would become a kind of secret society. We would probably have to come up with a special handshake and some obscure Latin motto. Then when we met other engineers at social functions, we could identify each other through the handshake and the password. Of course, conversation would have to be guarded because of the no-fraternization rule.

"Oh, so you're an electric . . . , I mean, maybe we have something in common," you say, glancing around nervously.

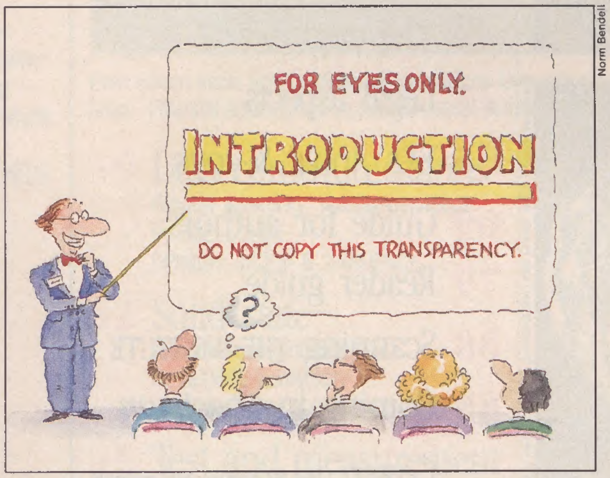
"Uhmm . . .," is the noncommittal reply.

"Uh, do you have a particular field?" you whisper quickly.

"Just . . ., just general electricity," the other engineer confides helpfully.

"Well, is it, like, large electricity, or, say, small electricity?"

At this point a prosperous-looking man in a three-piece suit approaches. "Perhaps . . . but I think it will rain tomorrow," you finish. No engineer would dare to look prosperous or wear a vest; this could be the intellectual property police.



Norm Bendell

Products would be designed in such a way as to protect trade secrets. All the important functionality would be encapsulated into very small, sealed plastic packages. Nobody would understand what was inside. Software would be written in abstract languages with huge amounts of extraneous, incomprehensible, diversionary code, much of which would be riddled with bugs. No product would work with any other product, unless it was from the same manufacturer. Standards and open architecture would be forbidden—a HAL computer would work only with HAL software. Corporate heaven would prevail.

Of course, engineering progress would be slowed to a creep in such an environment. The world would be deprived of advanced computer games, boom boxes, and stealth bombers. On the other hand, engineers would be guaranteed steady employment. The term "not invented here" would assume a new and frightening meaning, and every company would need its own stable of wizards.

An intellectual property expert reading this fanciful scenario would certainly be entitled to protest. "Let's be reasonable here," the expert would say. He would point out that in reality there are two kinds of information. There is green information, which can be shared with anyone, and red information, which needs to be kept proprietary. Green information has to do with theory and other mathematical stuff that is incomprehensible to lawyers, whereas red information is the real stuff—how to build a best-selling widget out of sand, that sort of thing.

The responsibility of the intellectual property people is to protect the company's own red information. The job of the industrial relations department is to uncover or steal other people's red information, while the engineers have the task of creating red information out of other people's green information. It's simple.

"Posh!" we would say to the so-called expert. Almost all information is actually yellow. Furthermore, many engineers feel that you have to give away some pink information just to balance your account in the international research community.

"Rubbish!" the savvy expert would say. Nobody keeps score. The journals and meetings are there for everybody, whether they contribute or not. Engineering knowledge is like a lighthouse, shining for one and all.

And so it goes. No one really understands how the world works, and perhaps the world itself is changing faster than we can understand it anyway. The thought even occurs to me that we might stop all meetings and publications, and then discover that no one had noticed or cared. Could we face the awful realization that no one actually does read the *Transactions*? I mean, we always joke about such things, but what if it were proved true? What if we discovered that information was really conveyed somewhere in the fourth dimension, that it seeps under windowsills and doorways, and that somehow every engineer just "knows" things without formally being told?

There are lots of fundamental mysteries here, but usually we just muddle through. As long as no one tries to really examine the process of information transfer, it seems to work fine. Up close, it just isn't very pretty.

Robert W. Lucky

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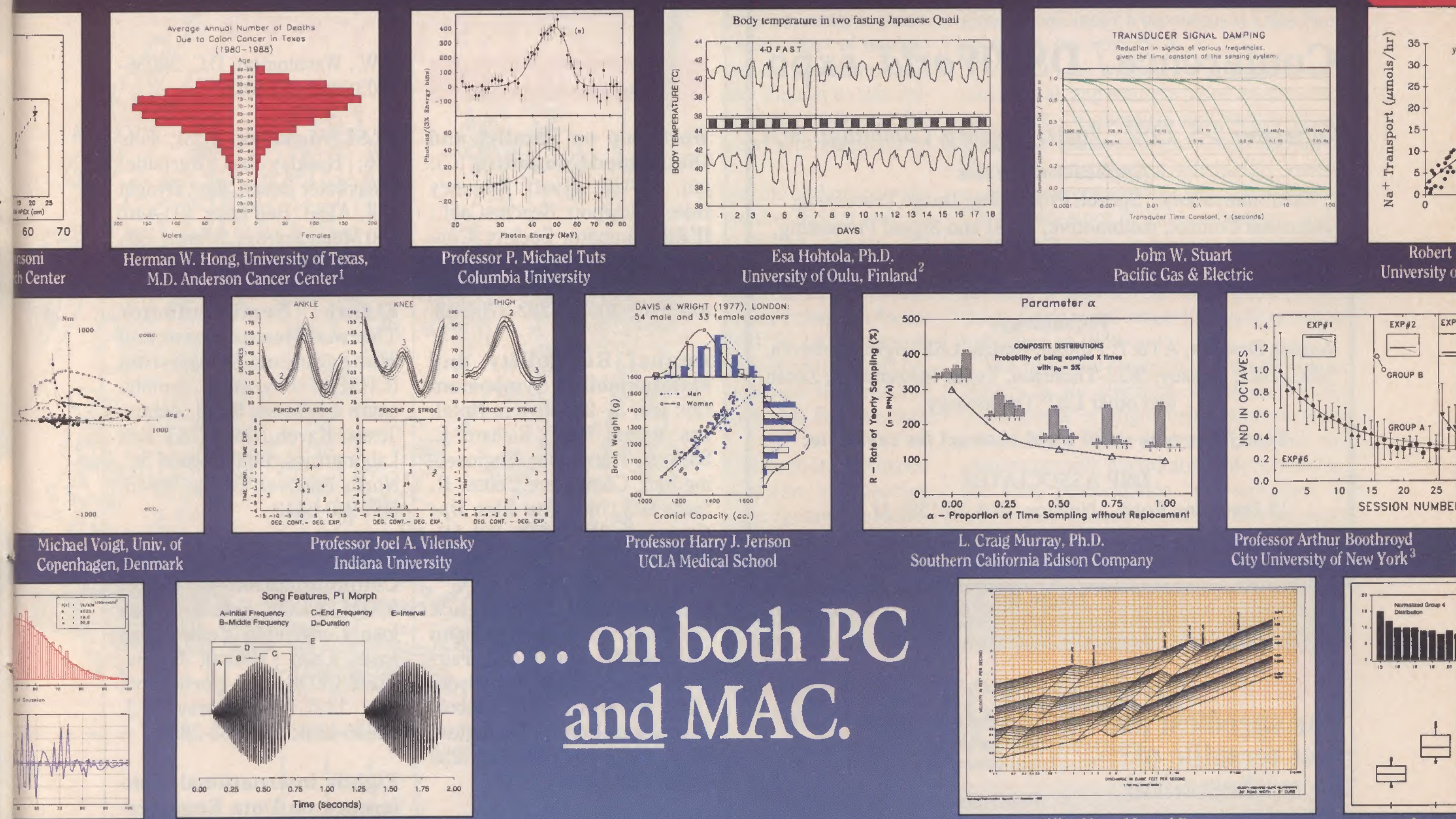

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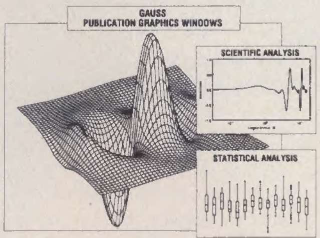

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Meetings, Conferences and Conventions

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Annual Reliability and Maintainability Symposium (R); Jan. 21–23; Riviera Hotel, Las Vegas, Nev.; Richard E. Sackett, Hernandez Engineering Inc., Commerce Center II, Suite 305, 7601 Ora Glen Dr., Greenbelt, Md. 20770; 301-441-3204.

International Conference on Wafer Scale Integration (C, CHMT); Jan. 22–24; Fairmont Hotel, San Francisco; Peter W. Wyatt, MIT Lincoln Laboratory, Box 73, Lexington, Mass. 02173-0073; 617-981-7232 or 617-862-9057.

Power Engineering Society Winter Meeting (PE); Jan. 26–30; New York Hilton at Rockefeller Center, New York City; J.G. Derse, 704 Timberbrooke Dr., Bedminster, N.J. 07921; 908-658-4042.

Eighth Optical Fiber Sensors Conference–OFS'8 (LEO); Jan. 29–31; Monterey Marriott Hotel, Monterey, Calif.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3893.

FEBRUARY

International Workshop on Research Issues on Data Engineering (C); Feb. 1–2; Sheraton–Mission Palms, Tempe, Ariz.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

VLSI Workshop (CS); Feb. 2–5; Holiday Inn, Surfside, Clearwater Beach, Fla.; Dwight Hill, AT&T Bell Labs, 3D-446, 600 Mountain Ave., Murray Hill, N.J. 07974; 908-583-7766.

Eighth Semiconductor Thermal Measurement and Management Symposium (CHMT); Feb. 3–5; Pamhlysmith 4 Seasons Hotel, Austin, Texas; Kaveh Azar, AT&T Bell Laboratories, 1600 Osgood St., North Andover, Mass. 01845; 508-960-6443.

Conference on Optical Fiber Communication–OFC '92 (COM, LEO); Feb. 3–7; San Jose Convention Center, San Jose, Calif.; Susan Evans, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3896.

Eighth International Conference on Data Engineering (C); Feb. 3–7; Sheraton–Mission Palms, Tempe, Ariz.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1906; 202-371-1013.

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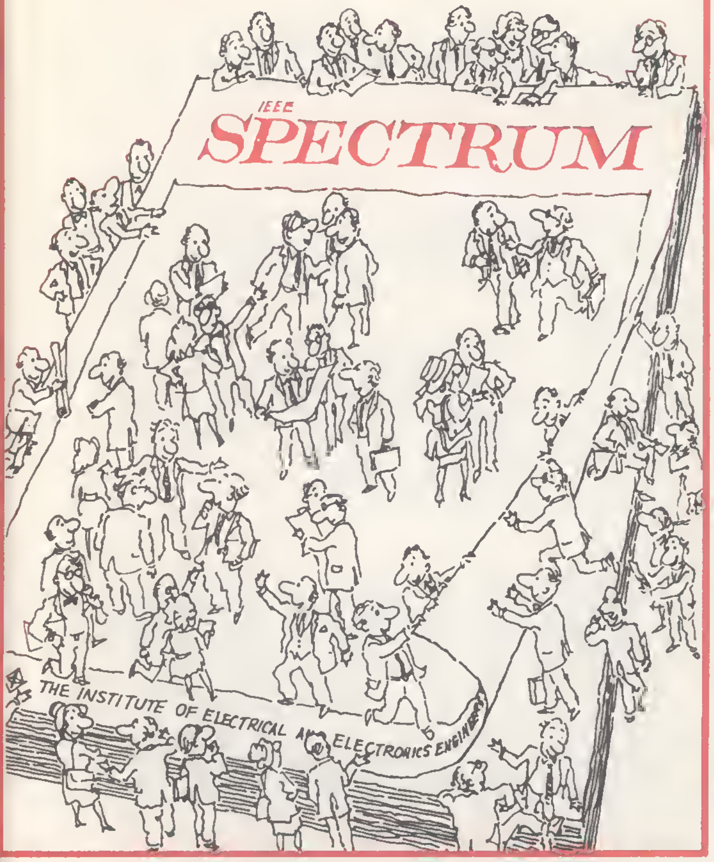

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Overall, the volume is strong on civil, mechanical, and transportation engineering, and weak on chemical and industrial engineering achievements. One chapter on electrical engineering adequately covers early power engineering and radio electronics, but does not include computers, solid-state electronics, or nuclear power. While their absence may disappoint some readers, perhaps it also reveals how undeveloped these fields were when the book was first published in 1956.

The principal strength of *Engineering in History* is its attention to detail; all the descriptions of engineering achievements are excellent, and, wherever possible, the authors provide quantitative information on the size, performance, and efficiency of different machines. However, this strength is also the book's weakness: this is a histo-

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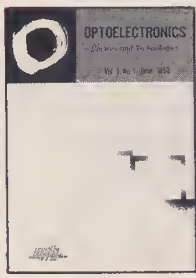

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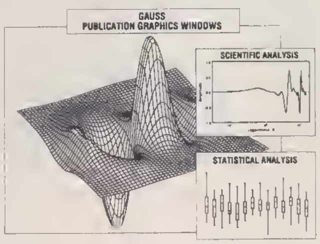

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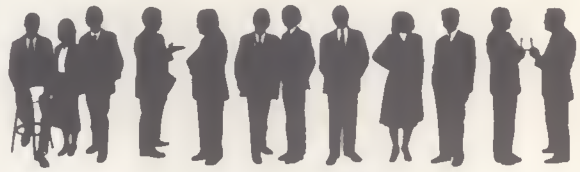

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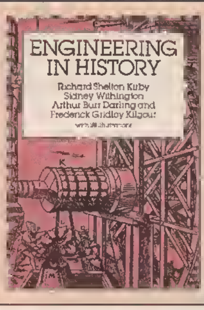
Books

Engineering, from the pyramids to paddle wheels

W. Bernard Carlson

Both engineers and historians should be delighted with the re-publication of this book by Dover. First published in 1956, *Engineering in History* is a highly readable, one-volume historical survey of technology, covering events from the agricultural revolution of 6000 B.C. to the development of control engineering in the mid-20th century. Although there are several multivolume histories of technology available in reference libraries, as well as numerous books covering the history of individual technologies, to my knowledge this is the only comprehensive, one-volume survey currently in print.

Engineering in History. *Kirby, Richard Shelton; Withington, Sidney; Darling, Arthur Burr; and Kilgour, Frederick Gridley,* Dover Publications, New York, 1990, 530 pp., $13.95.



The book was the joint effort of practicing engineers, engineering professors, and professional historians. Thanks to this collaboration, the book neatly balances the broad sweep of history with attention to technical detail.

In the early chapters, the authors provide concise descriptions of the ancient civilizations of Mesopotamia, Egypt, Greece, and Rome, so that each one's engineering accomplishments are placed in an overall historical framework. Later chapters focusing on European and U.S. developments offer less historical information, probably because the authors assumed that readers would already be somewhat familiar with such events.

Throughout the volume, there are excellent descriptions of major engineering landmarks—such as the pyramids, cathedrals, the Newcomen steam engine, and the Brooklyn Bridge—as well as fascinating details about forgotten projects—such as the 5.5-km hard rock tunnel that Roman engineers cut under a mountain at Lake Fucino in the 1st century A.D.

Overall, the volume is strong on civil, mechanical, and transportation engineering, and weak on chemical and industrial engineering achievements. One chapter on electrical engineering adequately covers early power engineering and radio electronics, but does not include computers, solid-state electronics, or nuclear power. While their absence may disappoint some readers, perhaps it also reveals how undeveloped these fields were when the book was first published in 1956.

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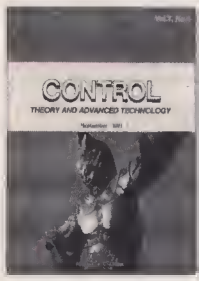

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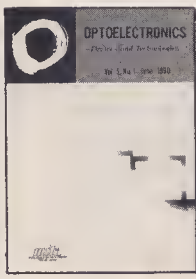

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Books

ry of machines, not a history of a discipline or profession. There is no discussion of the evolution of engineering knowledge, other than the obligatory mention of the importation of science, beginning in the 17th century.

All the engineers mentioned are treated as heroic individuals, but we do not learn how their social and cultural contexts informed their work. For example, the authors tell us little about how and why military engineers emerged as a professional group during the Italian Renaissance or why Englishmen such as James Smeaton chose to create a coherent body of engineering knowledge about waterwheels and steam engines in the 1700s.

Moreover, there is only cursory coverage of the impact of engineering on society; the authors were satisfied to show that engineering enhanced the total material and economic well-being of Europe and the United States without considering how it had changed the quality or tempo of life. Finally, the volume focuses exclusively on European and U.S. developments, and offers no discussion of non-Western contributions. While such an oversight may have been excusable in 1956, the increasing globalization of engineering makes it necessary for Western engineers to be aware of the technological accomplishments of Japanese, Chinese, Indian, and Arabic cultures.

Despite its weaknesses, I would recommend this book to engineers. The sheer number of remarkable accomplishments included in its pages is inspiring and reminds us of the tremendous impact engineering has had—and continues to have—on human civilization.

Furthermore, an awareness of the various roles played by individual engineers in history challenges modern-day practitioners to realize that their positions in society are not fixed, but subject to change. There are few limitations on either the design of machines or the social roles of engineers.

But above all, I would agree with the poet and novelist Sir Walter Scott that history gives the professional a breadth of vision. Speaking of lawyers (but he could well have been speaking of engineers), Scott wrote: "A lawyer without history or literature is a mechanic, a mere working mason; if he possess some knowledge of these, he may venture to call himself an architect." *Engineering in History* provides an introduction to the rich history of engineering that can create and sustain such a vision for today's engineering profession.

W. Bernard Carlson (M) is assistant professor of humanities in the School of Engineering and Applied Science at the University of Virginia in Charlottesville. He is author of Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, 1870-1900 *(Cambridge University Press, New York, 1991).*

Recent books

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Optical Fiber Communications, 2nd edition. *Keiser, Gerd*, McGraw-Hill, New York, 1991, 4612 pp., $52.95.

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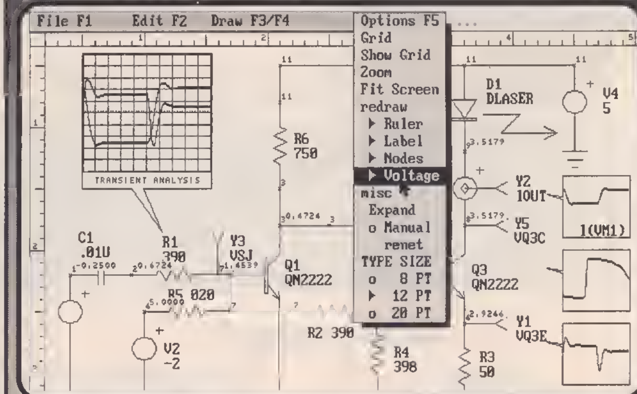

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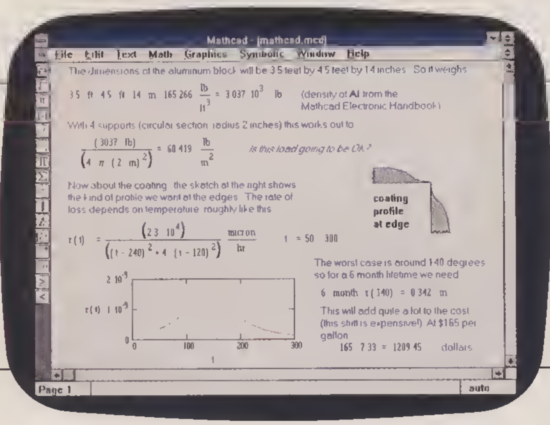

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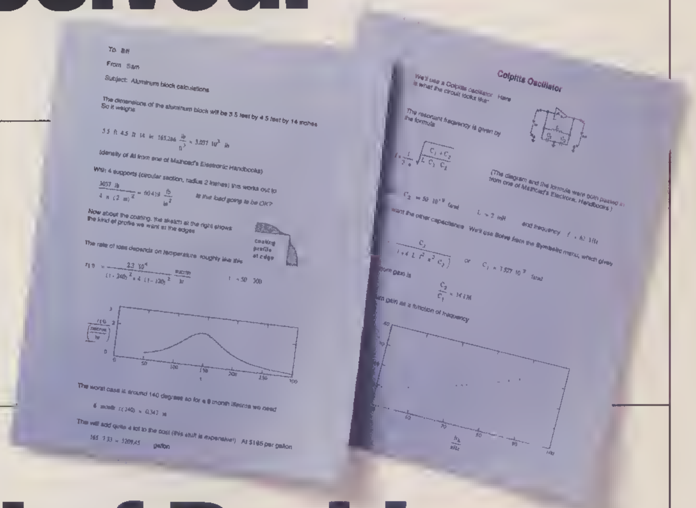

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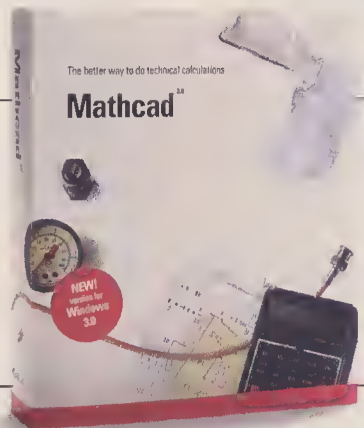

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Forum

Reviewing coprocessors

I was disappointed by Warren E. Ferguson Jr.'s article "Selecting math coprocessors" [July, pp. 38-41]. There were several distortions in it.

First, despite Ferguson's claim for the need for math coprocessors, a relatively small percentage of current commercial software packages take advantage of such devices. Furthermore, those that do are often encumbered with considerable overhead, such as a graphical user-interface (GUI), fragmented code, and suboptimal compiling procedures that considerably reduce the theoretical improvement of adding a math coprocessor.

A case in point is Microsoft Corp.'s Excel, which "spends lots of time doing graphics and little time doing computation. About 5 percent of its calls are floating point, while 95 percent are screen computations" (Martin Marshall, "Coprocessors Don't Always Help," *Infoworld*, Nov. 5, 1990, p. 29). Consequently, instead of an improvement of a factor of 5–10 in recalculation speed, results on the order of 50 percent (or 1.5) are common (Marshall, ibid.).

Second, Ferguson's table, "Characteristics of representative math coprocessors," is misleading. It is hardly a complete list of coprocessors, omitting the AMD, IIT, and other models. The clock cycles in the table suggest that the Cyrix coprocessors have a significant speed advantage over those of other brands. This is hardly if ever the case in real-world applications, as the *Infoworld* article cited above elaborates and as does Winn Rosch of *PC Magazine* in much greater detail ("Math Coprocessors: Fact or Fantasy," Feb. 12, 1991, pp. 301–22).

Third, another point made by Ferguson for selection purposes is power consumption, on which the Cyrix coprocessors score well. However, this issue is overblown for all but laptop computers. Any PC with a decent power and thermal dissipation system can handle the added power and heat requirements of a coprocessor system without, as Ferguson claims, "shorten[ing] the lifetime of both the math coprocessor and the PC in which it is installed."

Fourth, Ferguson also discusses the advantages of memory-mapped coprocessors, such as the Weitek 3167 and Cyrix EMC87; yet this too is overblown for most PC, even scientific PC, users. For starters, these memory-mapped devices are relatively expensive, particularly given the recent plunge in coprocessor price. (An 80387, 33-MHz class coprocessor now has an under-U.S. $200 street price, while memory-mapped devices are much more expensive.) Memory-mapped devices require specific upper memory block (UMB) addressing, such as starting with $C0000_{16}$.

Unfortunately, this UMB region is typically used to cache the videographics card BIOS on most high-performance Intel 386- and 486-based PCs, thus requiring the user to remap UMBs to use the memory-mapped coprocessor. Even worse, very few (perhaps 1 percent or fewer) commercial software packages support memory-mapped coprocessors.

While compilers have been developed by several companies that support Weitek Corp.'s memory-mapped coprocessor, test results reported are generally highly machine specific, and entail considerable hand-coding to milk the last ounce of performance from the compiler and memory-mapped coprocessor.

Ferguson fails to state two obvious steps—neither involving 80387-class coprocessors—that most scientific PC users can take to greatly improve application performance. The first is to purchase an Intel 486-based PC, now that the price on such machines is plummeting.

The second is to make sure, when purchasing a high-performance (386 or 486) PC, that the static RAM cache size is over 64K. The cache-less 386 or the limited cache on the 486 is ineffective in dealing with application or, even worse, scientific programs that manipulate large blocks of data or involve multiple code segments.

Edmund H. Conrow
Redondo Beach, Calif.

The author responds:
The third full paragraph of my article clearly states its focus: math coprocessors for Intel 80386 and Motorola 68030 central processing units (CPUs). My reasons for this stemmed from estimates that in 1991 PCs built with Intel 80386 CPUs (and compatibles) would outnumber those built with Intel 80486 CPUs by five to one. Furthermore, a significant fraction of these PCs is of the laptop or notebook variety. Therefore I addressed the article to the majority of people buying PCs in 1991.

For those interested, the AMD 80C287 is a lower-power CMOS implementation of Intel's original 80287. The clocks per instruction for the AMD 80C287 should agree precisely with those quoted in the table for the Intel 80287 since they both use the same microcode. Regrettably, I could not include information about IIT's product line, since they never supplied me with it.

Conrow states that spreadsheet users typically should expect a 50 percent improvement in recalculation speed when they add a math coprocessor to their PC. This means that a 25-MHz PC with a math coprocessor would outperform a 33-MHz PC without one. I would be pleased if spending $200 would give a 25-MHz PC I owned better calculation performance than I would obtain by purchasing a 33-MHz PC.

One point I did not make in my article is that 80286- and 80386-based PCs are far from dead. Software vendors still provide versions of their applications that run on Intel 80286s.

Do memory-mapped math coprocessors offer more bang for the buck? On Intel 80386-based PCs, memory-mapped coprocessors, like the Cyrix EMC87 or the Weitek 3167, do offer significantly improved performance, at a price more people can afford.

Finally, I believe current prices for Cyrix and Weitek memory-mapped coprocessors are lower than last year's prices of standard math coprocessors.

Corrections

On p. 36 of the November 1991 issue, the list of "Representative electromagnetic design and simulation software" should have included FLUX2D/FLUX3D (2-D/3-D second-order finite elements) and PHI3D (3-D boundary elements). These packages have been on the market since the early 1980s and are considered to be the leading electromagnetic computer-aided design programs in Europe. These programs handle 2-D and/or 3-D electromagnetic static, ac, and transient, thermal, and coupled magneto-thermal nonlinear anisotropic problems. They may run on any Unix/X11 platform (HP, Sun, Apollo, IBM, or DEC) and on DEC/VMS systems. The programs are distributed in the United States by Magsoft Corp., 1223 Peoples Ave., Troy, N.Y. 12180; 518-271-1352.

On p. 66 of the November issue, the Hewlett-Packard Co. listing under data acquisition software should have read: Hewlett-Packard Co., 11310 Pruneridge Ave., Cupertino, Calif. 95014, 800-752-0900.—*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contact: Forum, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017, U.S.A.; fax, 212-705-7453. The Compmail address is ieeespectrum.

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Graphics

New graphics standard challenges stalwart

Those who write software for high-performance graphics systems must make one of the computer industry's most fundamental tradeoffs: performance vs. portability. But if a graphics library from Silicon Graphics Inc. proliferates as its backers hope it will, some programmers may finally have it both ways.

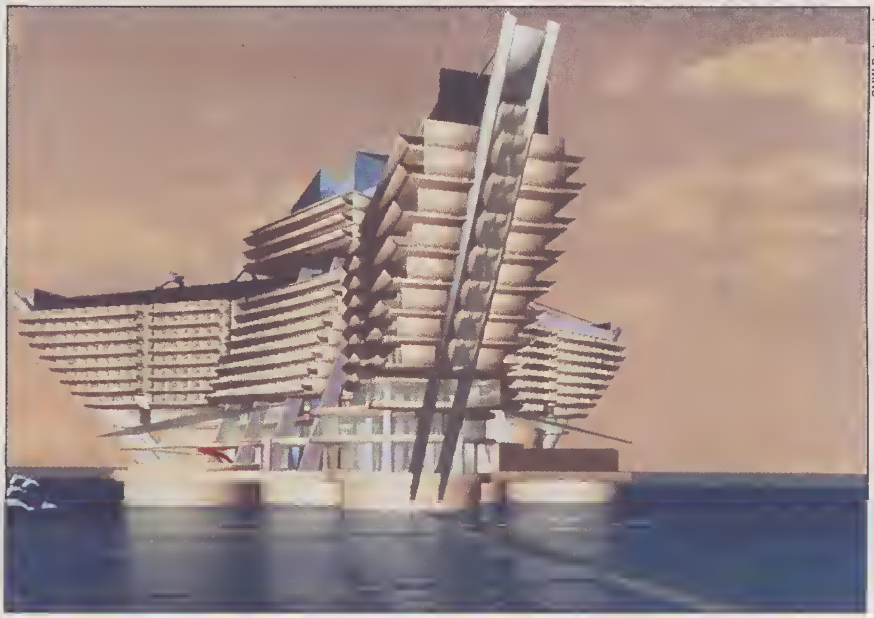
For about five years, the Programmers' Hierarchical Graphics Standard (Phigs) has been popular, and it has been endorsed by the American National Standards Institute (ANSI) in Washington, D.C. However, it is to three-dimensional graphics what Fortran is to technical computing: widely used but widely maligned as inadequate where performance is paramount.

"Phigs is a victim of the classic standardization process: it got old in the process of becoming good enough to use," said Joan-Carol Brigham, an analyst with International Data Corp. in Framingham, Mass.

The problem revolves around the graphics calls, the commands that, when translated into hardware or software operations, rotate an image on the screen, change its illumination, or perform some other function. As its name implies, Phigs works well where the graphics data lends itself to hierarchical organization. In a mechanical computer-aided design program, for example, an aircraft can be analyzed at several levels: at the top is the entire body; at the next level, the fuselage, airframe, wings, and control surfaces; then the engines, actuators, fuel tanks, and so on.

But increasingly, engineers and scientists are using computer graphics to evaluate, or "visualize," complex phenomena ill-suited to hierarchical representation. For example, simulating the flow of air over an airplane's wing or the forces within an atomic nucleus, or producing an image of a human kidney from magnetic resonance data, can all be difficult to force into Phigs's highly ordered structure.

For these and similar 3-D imaging needs, vendors of high-performance graphics hardware typically write their own group of graphics calls, or library. More direct control of the hardware is ensured, and thus higher performance, but compatibility is sacrificed: the applications written with the library will run only on the vendor's hardware.



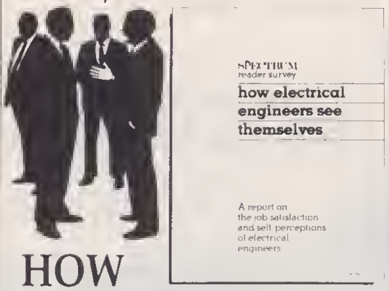
GMW Partnership

A perspective view of a proposed offshore hotel in Singapore was created with Silicon Graphics Inc.'s Iris GL graphics library.

Silicon Graphics believes it has a better way: it is offering its own Iris Graphics Library (Iris GL) for licensing to other vendors. Although the Mountain View, Calif., company's share of the overall workstation market is not large, it dominates the market for the highest-performance graphics workstations—a position that it hopes to leverage in promoting its library.

"You get two kinds of standards in the computer business," noted Carl Machover, president of Machover Associates Corp., a White Plains, N.Y., consulting firm. "There

Spectrum EE Job Satisfaction Poll Report Available



HOW ELECTRICAL ENGINEERS SEE THEMSELVES

Publication No. THO254-3
IEEE Members $7.50 List $20.00

Electrical engineers, while generally satisfied with their job and their profession, may be growing less optimistic about both.

IEEE Spectrum conducted a poll on job satisfaction last year and received responses from nearly 800 members. The results of the poll, which features a section that explores the image engineers have of themselves, can be found in the just-published, 48-page report entitled *How Electrical Engineers See Themselves*. Surprisingly, although most respondents were happy with their profession, fewer today would recommend that a family member or friend pursue electrical engineering than would have done so five years ago.

The report addresses which job functions, among the many for which an engineer is responsible, detract from job satisfaction and which contribute to it. In addition, the answers are catalogued for a section of the survey that asked how far respondents expected electrotechnology to progress by the year 2000. Included are some of the illuminating written comments that accompanied many of the survey responses.

For information on how to order *How Electrical Engineers See Themselves*, use the Reader Service Card.

Circle No. 45

Graphics

are standards that are industry or agency sponsored, and *de facto* standards. Phigs is an industry standard, and GL is a *de facto* standard." In fact, well before Silicon Graphics' Sept. 17 announcement that it would make Iris GL available, the company had already licensed it—to Microsoft Corp., Redmond, Wash., and to IBM Corp., which has offered it, as well as Phigs, on its RS 6000 workstations for almost two years.

Silicon Graphics and three other early supporters of the Iris GL—Compaq Computer, Digital Equipment, and Intel—have formed a governing board that is now preparing a new draft for general release. This draft, version 5.0, will "eliminate a lot of the machine-specific dependencies of earlier versions of the GL, allowing each individual company to optimize it for their own hardware," said Bill Glazier, manager of the Iris GL licensing program at Silicon Graphics.

The group hopes to have 5.0 ready by next July 1, Glazier said. Prices will begin at US $5000 for academic users content with a detailed, written specification and other documentation, and peak at about $300 000 for corporate users who want all the source code needed to implement the GL on their machine, plus the right to redistribute modified source code to any customers who are also licensees. Some corporate users will also have to pay royalties of $5 per workstation.

While the debate over the relative merits of Phigs and Iris GL rages, some wonder if it is overblown. "It's almost a religious discussion," said Albert J. Bunshaft, program manager for graphics development at IBM's Graphics Systems Organization in Kingston, N.Y. "In most cases, you can write a given application in Phigs *or* GL. It's like writing an application in Pascal or C."

One of the few major differences between Phigs and GL has been the way in which they handle graphics data before sending it to the screen for display. GL features immediate-mode graphics, in which there is no delay, while Phigs is typical of retained-mode graphics, in which data is stored before being sent to the screen. However, all versions of GL have had a retained-mode capability, and some current (and proposed) versions of Phigs have some immediate-mode capabilities.

"What's happening is that they're incorporating the best parts of each other, although none of the vendors present it that way," Bunshaft said. "I don't think you'll see one win out over the other in the long run. If someone asks, 'Which one will people be using five years from now?,' the answer is, 'Both.'"

COORDINATOR: Glenn Zorpette

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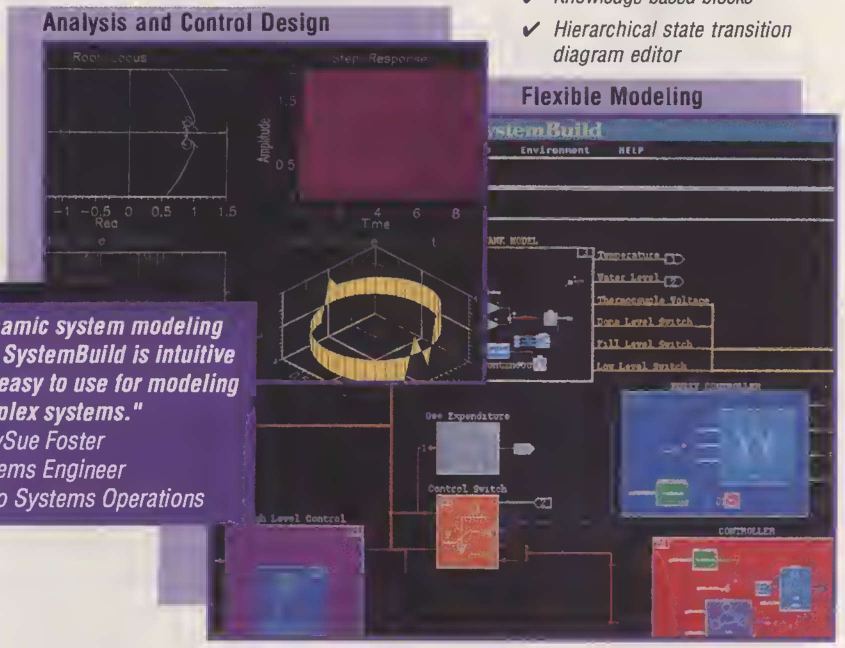

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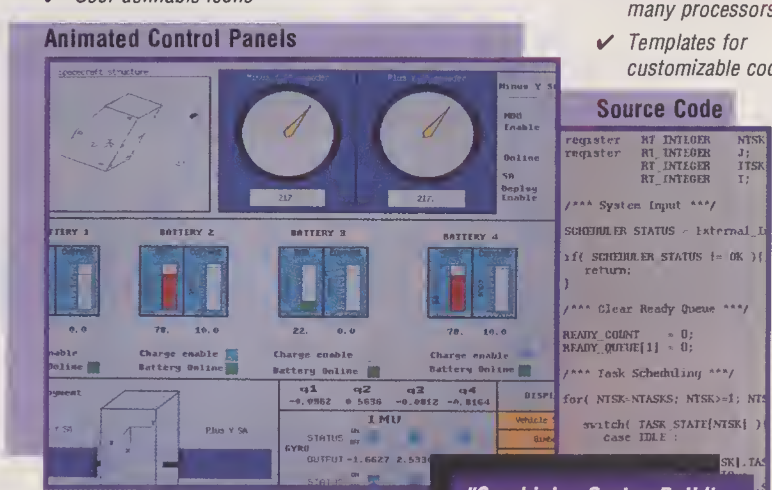

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Circle No. 22

The engineer at large

U.S., Southeast Asian research centers pair off

West will meet East after all, at any rate in some areas of research, if the Asian Pacific Economic Cooperation (APEC) Partnership for Education has its way. The U.S. organization is sponsoring five partnerships between university research centers in the United States and Southeast Asia—specifically, Malaysia, Singapore, and Indonesia. The intent is for the partners to conduct joint programs of research, education, and information exchange.

The U.S. centers were picked for their success in establishing research ties among academia, industry, and government. All are funded by the National Science Foundation, Washington, D.C., to do engineering research in electronics-related and other areas in cooperation with industry.

Multimedia, multilingual knowledge-based engineering will be the focus of the Parallel, Distributed and Intelligent Systems Center at the University of Pittsburgh and the Department of Mathematics of the University of Malaysia along with the Institute of Systems Science of the National University of Singapore. The Design of Analog-Digital Integrated Circuits Center at Washington State University in Pullman will exchange ideas on such circuits with the Universiti Teknologi Malaysia. The Data Storage Systems Center at Carnegie Mellon University, Pittsburgh, will look into that technology with the Magnetic Technology Centre of the National University of Singapore.

Advanced ceramics will be the focus of the Ceramic Research Center at Rutgers University, New Brunswick, N.J., and the Standards and Industrial Research Institute of Malaysia. Lastly, the Hazardous Substance Management Center at the New Jersey Institute of Technology, Jersey City, will collaborate on its specialty with the University of Indonesia in Jakarta.

The extent of the cooperation within the partnerships will vary. In general, they will exchange researchers and graduate students and organize short courses and lectures for each other. Each U.S. partner will receive US $100 000 over two years from the APEC Partnership for Education, which is administered by the U.S. Agency for International Development.

EE grad numbers down . . .

The number of bachelor's degrees awarded in electrical engineering in the United States dropped by more than 7 percent this past academic year, to 19 858 from 21 385 the year before, according to a survey by the American Association of Engineering Societies' (AAES') Engineering Manpower Commission. Overall, the number of bachelor's degrees in engineering granted decreased by a far lower rate—3 percent—to 63 987 in the 1990–91 academic year from 65 967 in 1989–90.

The decline in the total number of engineering students has been recorded now for several years. It coincides with decreases in the overall number of college students.

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Circle No. 13

Engineer at large

at 600 colleges; the number of degrees granted in each engineering field; percentages of men, women, and minorities studying various engineering fields; and cumulative data from previous surveys. The publication sells to AAES members for US $140, to others for $230. It is also available on floppy diskettes for $595 to members and $795 to others. *Contact: American Association of Engineering Societies, 1111 19th St., N.W., Suite 608, Washington, D.C. 20036-3690; 202-296-2237.*

. . . but more will be hired

In a survey of 342 employers, including some that hire engineers, the College Placement Council found that a majority of them planned to hire more graduates during the 1991–92 academic year than they had in 1990–91. In fact, some of the employers said they had done no recruiting at all last year.

Overall, 61 percent planned to hire 8.5 percent more new graduates in 1991–92. Even so, almost two out of three of the employers doubted the recession is over.

Starting salaries were projected to increase this year, but never by more than the inflation rate. According to the survey, new bachelors in engineering and computer science can expect 3.1 percent higher salaries than they would have been offered a year ago, while at the master's level, engineering graduates can expect a 4.3 percent hike. Masters in business administration can expect to start at salaries 3.4 percent higher.

Employers said turnover had dropped and acceptance rates and the numbers of unsolicited résumés they received had risen. *Contact: College Placement Council, 62 Highland Ave., Bethlehem, Pa. 18017; 215-868-1421; fax, 215-868-0208.*

The future of engineering education

It's time to begin restructuring our educational process to instill into tomorrow's engineers "the genius for integration," to use a phrase coined by philosopher José Ortega y Gasset. So wrote Stephen D. Bechtel Jr., chairman emeritus, Bechtel Group Inc., of San Francisco, in an article in the December 1991 *Rochester Engineer* published by the Rochester (N.Y.) Engineering Society.

Bechtel then quoted Joseph Bordogna, assistant director for engineering at the National Science Foundation in Washington, D.C., and dean emeritus of the School of Engineering and Applied Science at the University of Pennsylvania, Philadelphia, that the goal is to give students "the ability to make connections among specialized areas of knowledge, to understand the relationships among seemingly disparate discoveries, events and trends, and to integrate them in ways that benefit the world community."

Several engineering schools are modifying their curricula to achieve such integration. Drexel University in Pennsylvania, for one, Bechtel pointed out, has a pilot program where hands-on engineering education begins in the freshman year, even though students have not yet mastered all the necessary science and math skills.

By tackling applied engineering projects early, students learn to define problems, consider alternative solutions, and deal with the environmental, financial, social and other issues they will face later on the job, Bechtel continued. And while they have an application for the new knowledge, students will also be motivated to learn the additional math and science fundamentals, he said.

"Students following this educational path seem likely to emerge with the broad, interdisciplinary skills that they'll need to turn ideas into reality in the 21st century," he added. And he concluded: "Now, as a profession, we need to commit ourselves to a nationwide revamping of our engineering educational process."

COORDINATOR: Dana Norvila

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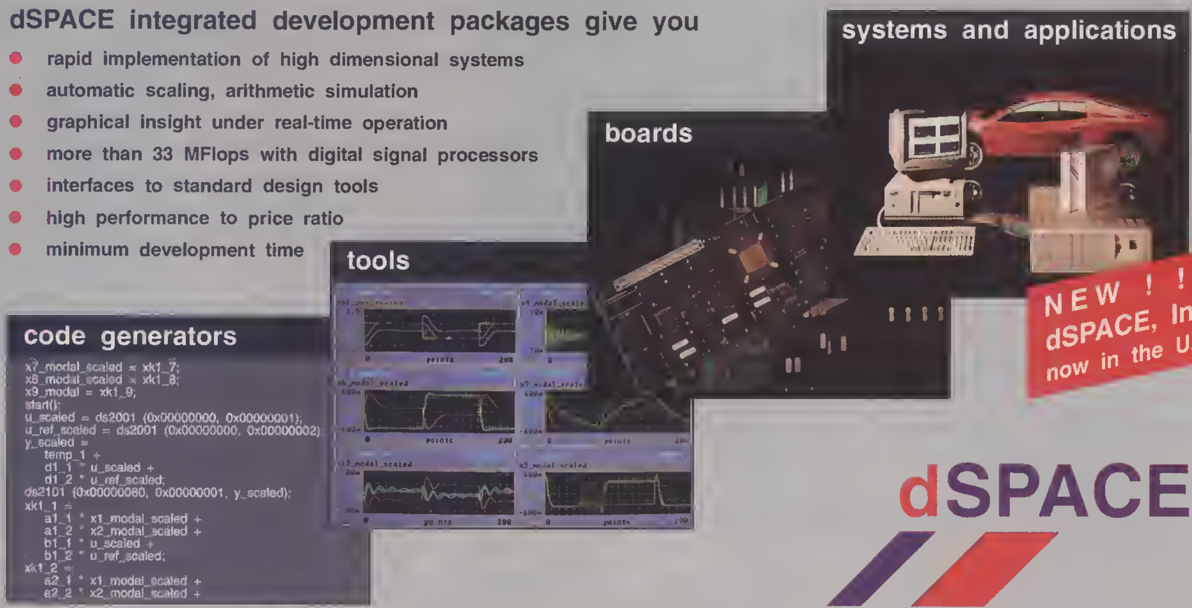

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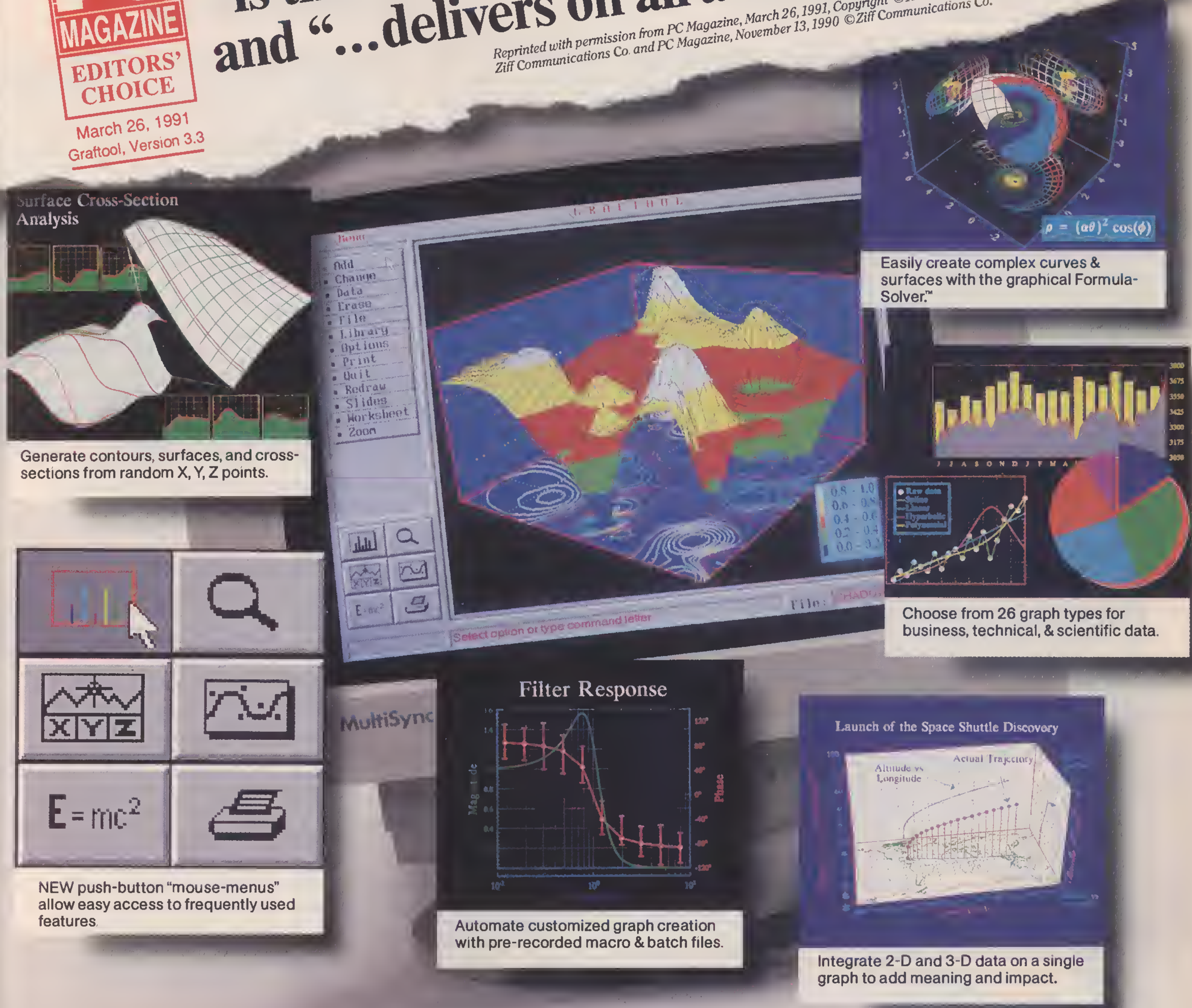

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Calendar

(Continued from p. 8)

Sixth International Photovoltaic Science and Engineering Conference (ED); Feb. 10–14; Hotel Taj Palace Intercontinental, New Delhi, India; B.K. Das, PVSEC-6 Conference, National Physical Laboratory, Krishnan Road, New Delhi—110012, India; (91+11) 572 6058; fax, (91+11) 575 2678.

International Conference on Intelligent Control and Instrumentation (Singapore Section); Feb. 18–21; Hilton International, Singapore; R. Devanathan, 200 Jalan Sultan, 11-03 Textile Centre, Singapore 0719; (65) 291 9690; fax, (65) 292 8596.

International Solid State Circuits Conference–ISSCC (Solid State Circuits Council, et al.); Feb. 19–21; San Francisco Hilton Hotel, San Francisco; Diane Suiters, Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-347-5900.

Applied Power Electronics Conference and Exposition (PEL); Feb. 23–27; Westin Hotel, Boston; Melissa Widerkehr, Courtesy Associates Inc., Suite 300, 655 15th St., N.W., Washington, D.C. 20005; 202-639-4990; fax, 202-347-6109.

Compcon Spring '92 (C); Feb. 24–28; Cathedral Hill Hotel, San Francisco; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

MARCH

First International Fuzzy Systems Conference (COM, IE, NN); March 8–12; Town & Country Hotel, San Diego, Calif.; Nomi Feldman, Meeting Management, 5665 Oberlin Dr., Suite 110, San Diego, Calif. 92121; 619-453-6222.

Fourth International Strategic Software Systems Conference (C, et al.); March 10–11; Von Braun Civic Center, Huntsville, Ala.; University of Alabama at Huntsville, Conference Office, SB/Box 309, Huntsville, Ala. 35899; 205-895-6372 or 800-448-4035; fax, 205-895-6760.

Southcon '92 (Region 3); March 10–12; Orange Country Convention/Civic Center, Orlando, Fla.; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045; 213-215-3976 or 800-877-2668.

18th Annual Northeast Bioengineering Conference (EMB); March 12–13; University of Rhode Island, Kingston, R.I.; William J. Ohley, Electrical Engineering Department, University of Rhode Island, Kingston, R.I. 02881; 401-792-2505.

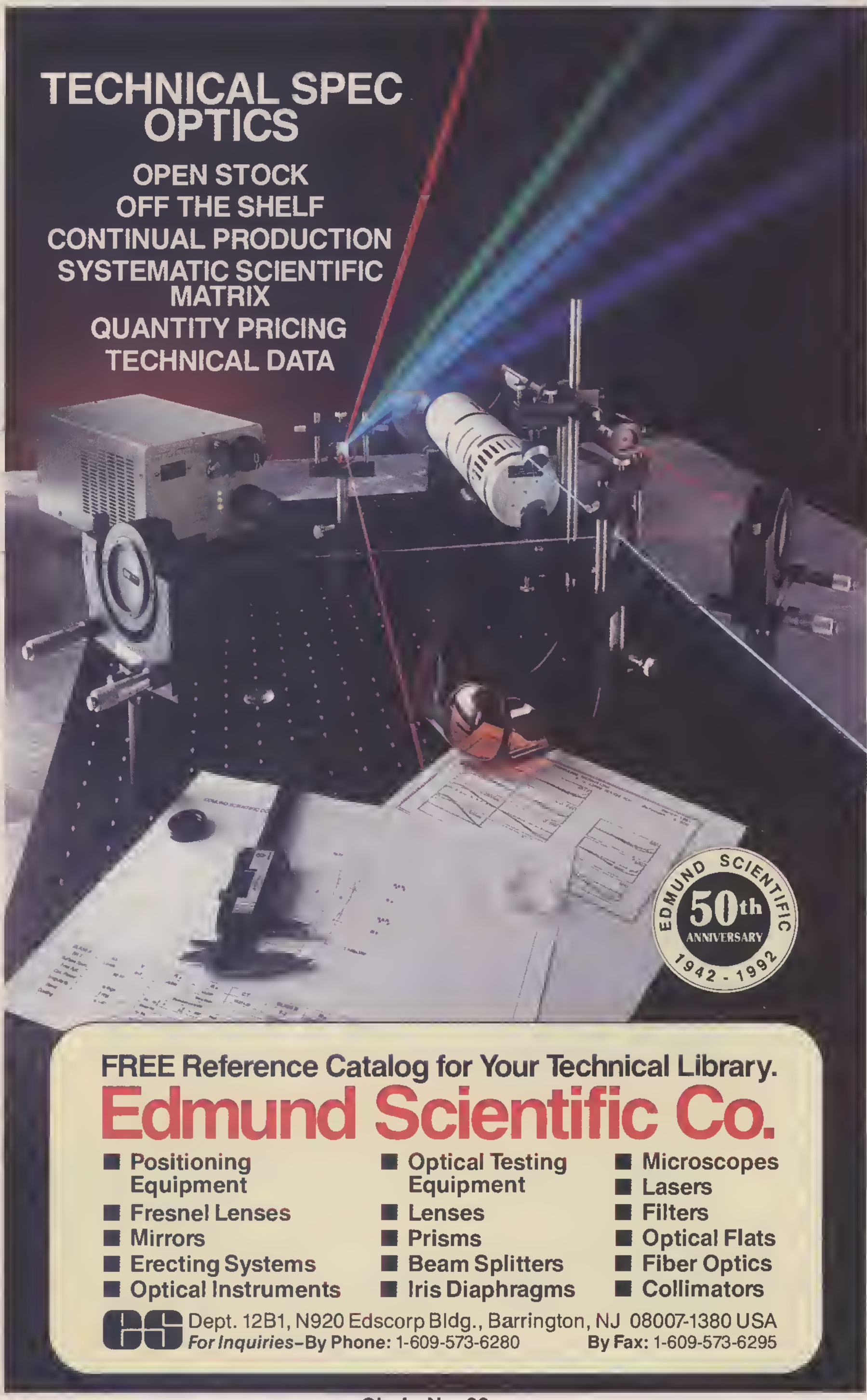
Fourth International Conference on Microelectronic Test Structures (ED); March 17–19; Catamaran Resort Hotel, San Diego, Calif.; Michael W. Cresswell, National Institute of Standards and Technology, B360 Technology, Gaithersburg, Md. 20899; 301-975-2072; fax, 301-975-2128.

International Zurich Seminar on Digital Communications (Region 8); March 17–19; Swiss Federal Institute of Technology, ETH-Zentrum, Zurich, Switzerland; Anne Schicker, Box CH-8340 Hinwil, Switzerland; (41+1) 937 2447; fax, (41+1) 938 1557.

Multichip Module Conference (ED); March 17–20; Cocoanut Grove, Santa Cruz, Calif.; Simon Wong, Stanford University, Electrical Engineering Department, CIS 202, Stanford, Calif. 94305; 415-725-3706.

Packaging, Interconnects, Optoelec-

(Continued on p. 20F)



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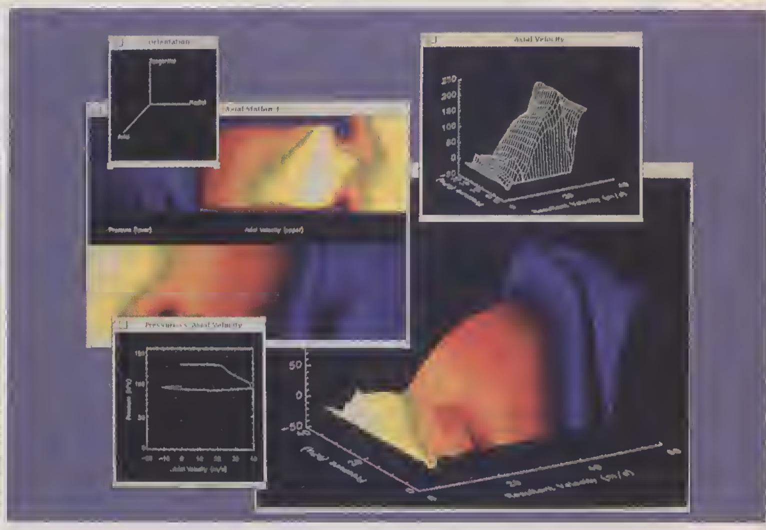

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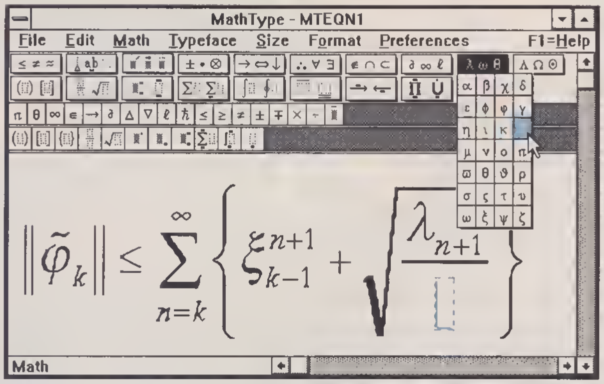

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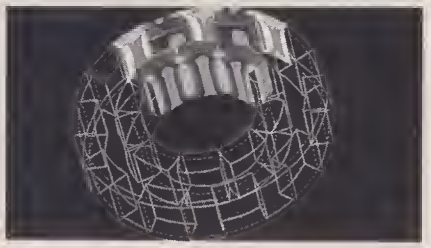

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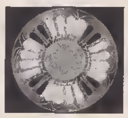

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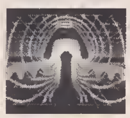

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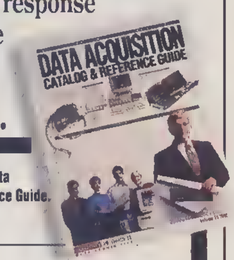

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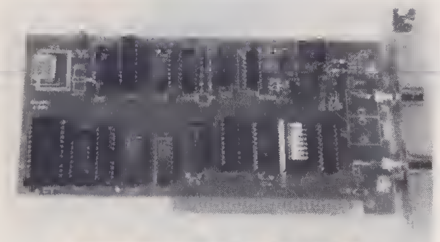

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(Continued from p. 20B)
tronics for the Design of Parallel Computers (LEO); March 18–19; Hyatt Regency Woodfield, Schaumburg, Ill.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3894; fax, 908-562-1571.

International Workshop on Intelligent Signal Processing and Communication Systems (C); March 19–20; International Convention Center, Taipei, Taiwan; Naohisa Ohta, NTT Transmission Systems Laboratories, 1-2356, Take Yokosuka-shi 238-03 Japan; (81) 468 59 2072; fax, (81) 468 59 3014.

International Conference on Acoustics, Speech and Signal Processing (SP); March 23–26; San Francisco Marriott, San Francisco; Marcia A. Bush, Xerox PARC, 3333 Coyote Hill Rd., Palo Alto, Calif. 94304; 415-494-4391.

Sixth International Parallel Processing Symposium (C); March 23–26; Beverly Hilton Hotel, Beverly Hills, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Reliability Physics Symposium (ED); March 30–April 2; Town and Country Hotel, San Diego, Calif.; Harry Schafft, National Institute of Standards and Technology, Building 225, Room B360, Route 270, Quince Orchard Road, Gaithersburg, Md. 20899; 301-975-2234; fax, 301-948-4081.

APRIL

11th Annual International Phoenix Conference on Computers and Communications (C, COM); April 1–3; Wyndham Paradise Valley Resort, Scottsdale, Ariz.; Joseph Urban, Department of Computer Science and Engineering, College Engineering and Applied Science, Arizona State University, Tempe, Ariz. 85287-5406; 602-965-2774; fax, 602-965-2751.

Network Operations and Management Symposium (COM); April 6–9; Peabody Hotel, Memphis, Tenn.; Jill Pancio, Pacific Bell, 7620 Convoy Court, San Diego, Calif. 92111; 619-268-6135; fax, 619-292-1509.

Fourth International Conference on Indium Phosphide and Related Materials (ED); April 21–24; Newport Sheraton, Newport, R.I.; Susan Evans, IEEE/LEOS Executive Office, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3896.

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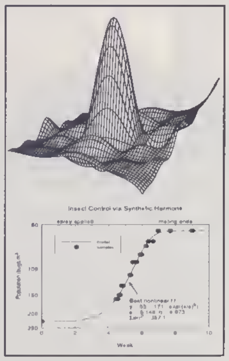

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Notification of acceptance/rejection will be sent by May 15, 1992. Accepted papers will be published in the Conference Proceedings. A camera-ready version of the paper must be received by **June 30, 1992.**

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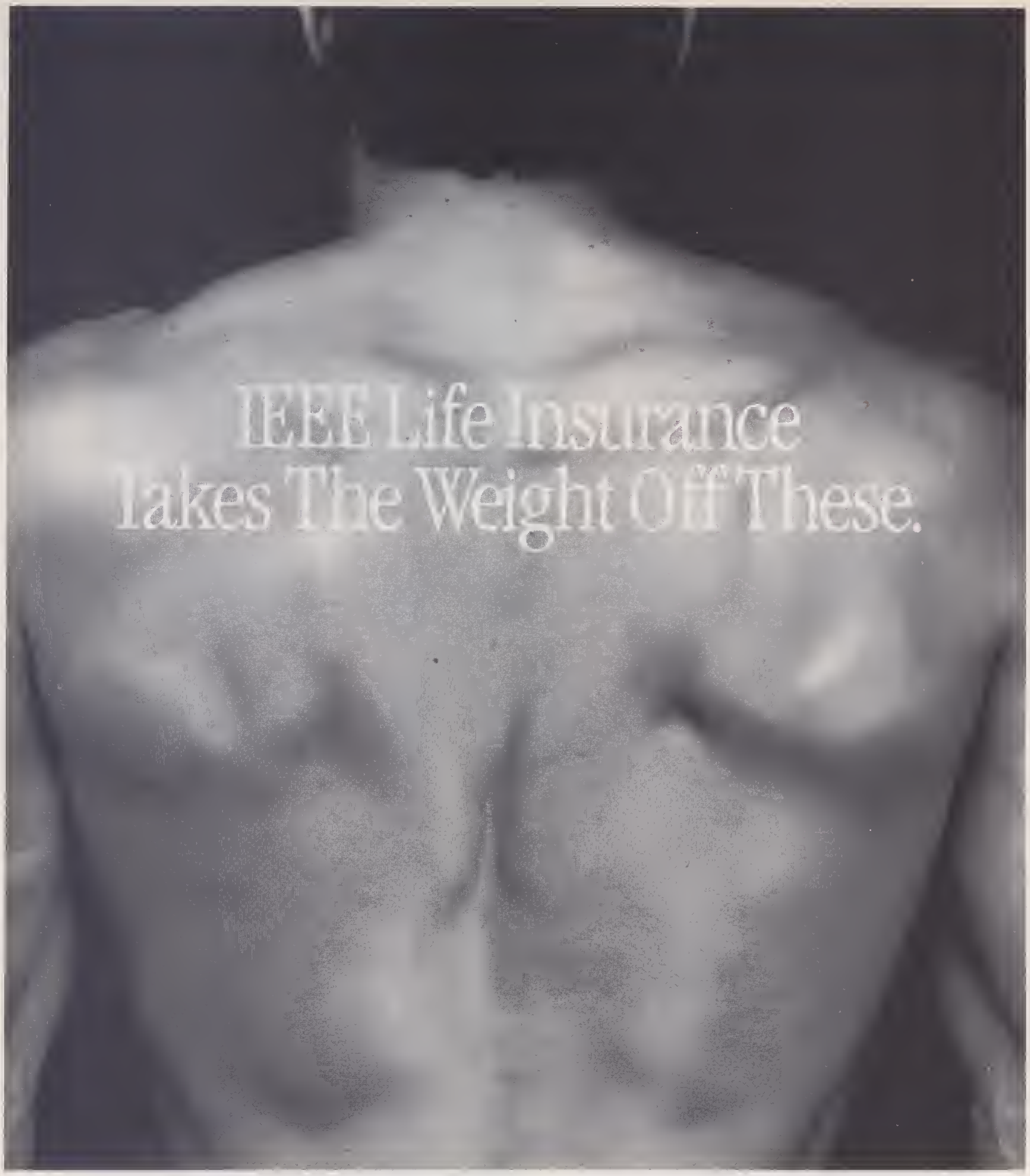

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WARC-92: setting the stage

Joel Miller

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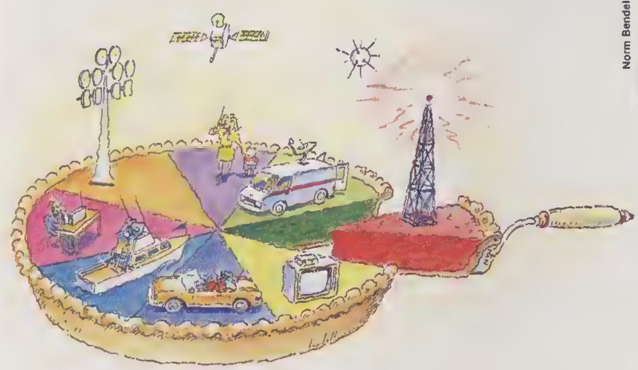
To juggle all of these demands, representatives of almost all the nations of the world periodically meet under the auspices of the International Telecommunication Union (ITU) to address spectrum management issues. The next such meeting, the 1992 World Administrative Radio Conference (WARC-92), will begin in February in Torremolinos, Spain, where delegates will consider frequency allocations for existing and new technologies.

Allocations on a worldwide basis are set out in the ITU's Table of Frequency Allocations. Perhaps the heart of the ITU's spectrum management legislation, it lists the current allocation of radio frequencies by geographical area and service (such as mobile, satellite, broadcast, and amateur).

BEFORE LEAVING FOR SPAIN. Of course, one cannot just show up at WARC-92 and be heard on a new issue. Matters taken up at a WARC must in general be on the WARC agenda, drawn up about two years before the actual conference.

Typically, the need for a WARC is determined by a previous WARC or by the ITU's Plenipotentiary Conference, which is the supreme organ of the ITU, having responsibility for establishing the ITU's overall policies and programs. WARC-92 evolved from the most recent plenipotentiary, held in Nice, France, in 1989. There, the delegates requested a conference addressing allocations for a variety of satellite and terrestrial services, including space communications, mobile radio services, digital audio broadcasting, and high-frequency international broadcasting. The agenda for WARC-92 was established the following year by the ITU's Administrative Council, a subset of the ITU's member nations.


Norm Bendell

Against the backdrop of the WARC agenda, ITU member nations developed and submitted proposals for spectrum allocation and related matters. These proposals, which may have been refined through bilateral and multilateral negotiations with other ITU member states before the WARC, form the initial input to the conference, analogous to bills introduced in a legislature. After review and further refinement by WARC committees, a single set of compromise proposals will be submitted to the full plenary of the conference—that is, to the entire assembly—for its consideration.

For the engineering community, participation at the national level is crucial, especially where industry input is invited. In the United States, for example, the Federal Communications Commission (FCC), being charged with regulation of nongovernmental radio

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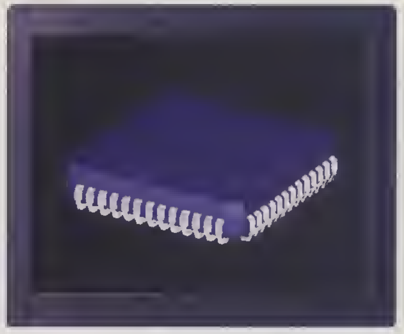

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Legal aspects

communications, issued three Notices of Inquiry, soliciting public comment on WARC-92 issues. In addition, the FCC established an Industry Advisory Committee in January 1990 to further develop the position of the private sector. The result of this process, a final report issued in June 1991, evidences a high degree of participation by the telecommunications industry as well as trade associations, municipalities, amateur radio organizations, and individuals. As illustrated by the report, certain of the public's comments influenced the FCC in its preparation of the U.S. proposals, which were formally submitted to the ITU by the U.S. Department of State.

MEMBERS ONLY. Although charged with deciding communications issues for the world at large, a WARC is not a town meeting open to everyone; admission is carefully controlled. As dictated by the ITU Convention, each member nation may send one delegation, which must carry diplomatic credentials. Moreover, only member nations can vote at a WARC and, regardless of size, wealth, or position, each has only one vote. Each country controls the makeup of its delegation, which typically includes foreign affairs officials, government communications specialists, and industry personnel.

In addition to member nations, the ITU will allow attendance by certain observers, such as representatives of regional telecommunications organizations, specialized agencies, and recognized private operating agencies authorized by a member state. The observer role may offer members of the technical community yet another opportunity to participate in a WARC.

FIRST COME, FIRST SERVED? The existence of an allocation for a given service is no guarantee that all nations will be able to obtain frequency assignments for that service. Indeed, frequency assignments and, in the case of the satellite services, orbital positions were traditionally granted on a first come, first served basis. For developed countries, this was an acceptable arrangement. But for those nations whose communications industries matured later, the demand for this extremely limited resource quickly outstripped available spectrum, especially in the case of satellite communications. Although lacking the communications infrastructure of the more advanced countries, developing nations wanted to ensure that they would be able to obtain a fair share of spectrum and the geostationary orbit for their own increasing communications needs.

Accordingly, in response to pressure from these nations, the ITU amended its convention in 1982 to provide that the allocations process should take into account "the special needs of the developing countries" [1982 International Telecommunication Convention, Art. 33(2)]. While this language appears to favor developing countries, it does not in fact give them an absolute priority or any special advantage. Rather, the amended provision has been interpreted thus far to require that the ITU evaluate the needs of both developing and developed nations on the same basis.

THE FINAL ACTS. The outcome of a WARC is embodied in a document called the Final Acts, containing everything agreed upon and signed by the member delegations. In the case of the United States, to the extent the provisions concern treaty instruments, the Final Acts must be ratified by the Senate in order to be recognized by the U.S. government. Once the allocations are in place, member nations can begin to avail themselves of these provisions by authorizing specific frequency assignments for their respective applications. For information on the technical issues before WARC-92, read next month's *IEEE Spectrum*.

Joel Miller is an attorney in private practice in New Jersey.

COORDINATOR: Trudy E. Bell

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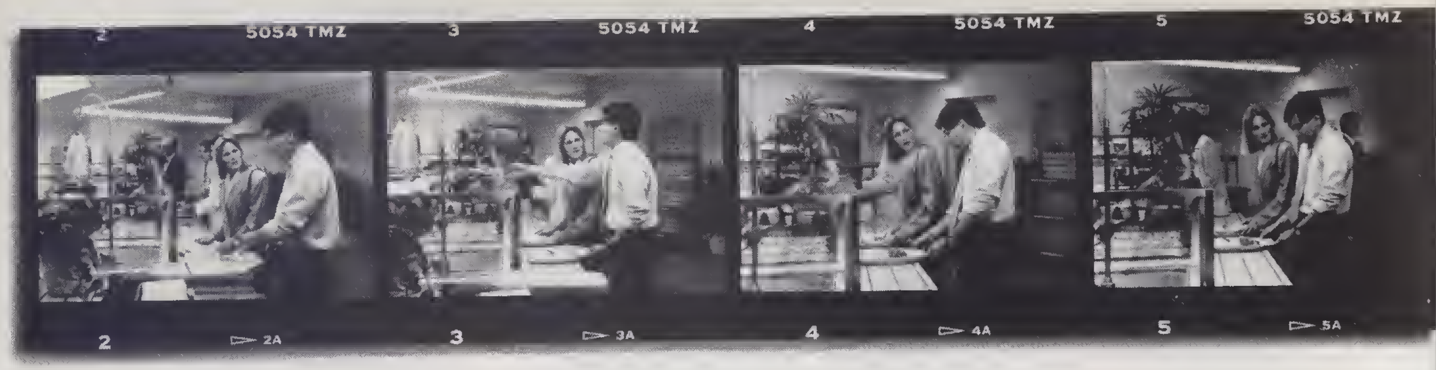
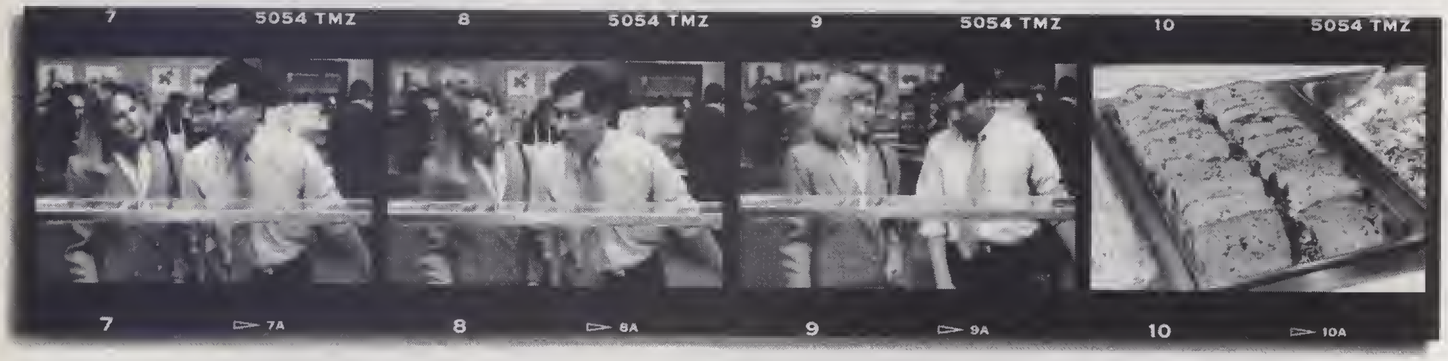
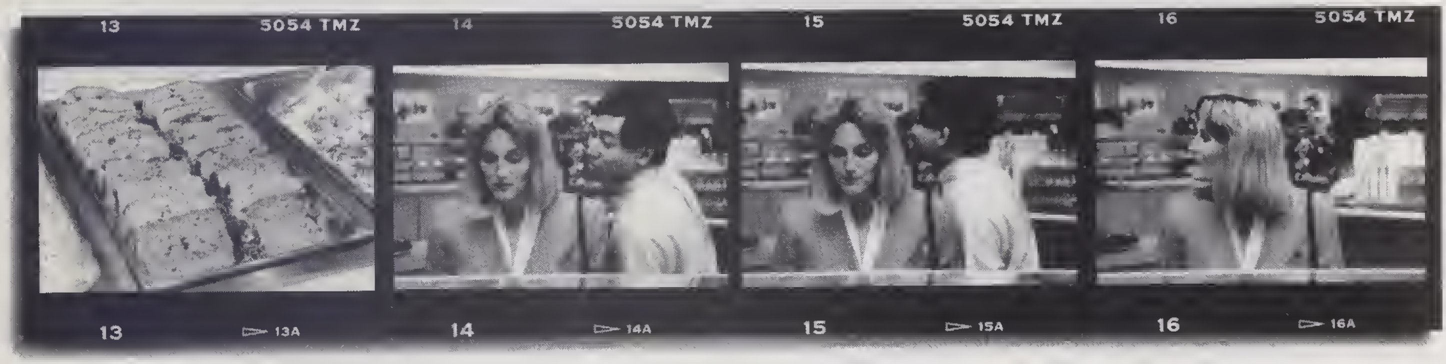


"So you're testing a prototype already?" *"Yep. Mmm, lasagne."* "Patents checked?"



"Wouldn't test otherwise." "Meet industry standards?" *"It'll comply...*



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Circle No. 3

JANUARY 1992 Volume 29 Number 1

The measurement explosion

The story—apocryphal, one supposes—goes like this. A Scottish farmer always had prize sheep to take to market, while neighboring farmers' sheep were consistently puny. When a visitor once asked him his secret, he said "While they're weighing their sheep, I'm fattening mine." A fundamental tool of engineers and scientists is that of measurement, but is it possible that, like the farmers' neighbors, we sometimes overdo it?

Norm Bendell

Engineers and scientists are trained in the scientific method, a central step of which is measurement. Lord Kelvin wrote: "When you can measure what you are speaking about and express it in numbers, you know something about it, and when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind." Good advice for scientists and engineers, but there are surely times when good decisions are made on the basis of less than complete data.

Sophisticated sensors, new measurement techniques, and the ability to make massive measurements and manipulate data rapidly means that traditional measurements can be made more efficiently and at low cost, and also that hitherto impossible measurements are now possible.

This bodes well for some. Lord Kelvin would have been ecstatic with today's tools. The ability to capture physical phenomena at higher speeds and microlevels should delight scientists. The new measurement milieu is also a boon to engineers and entrepreneurs. As one example, petroleum engineers can measure and map oil-bearing terrain in three dimensions to reduce the risk of drilling dry holes and to increase the probability of selecting rich wells.

On the other hand, the ease and speed with which measurements can be made suggests the possibility of instrumentation or measurement overkill. Consider the vast quantity of telemetry data transmitted to ground stations that has never been processed. Programs for processing some of it have become obsolete so that it may never be used (just as well, say some, who think much of it was unnecessary). Consider also the petroleum prospecting data mentioned earlier. Some of it, too, may never be decoded because of the oscillating economies of worldwide oil production. In the meantime, the storage of such data requires more and more space, so that data once considered "free" may no longer be so, and some may have to be purged because of high storage costs.

Meanwhile, the management information specialists, thanks again to our own technology, find ingenious and inexpensive ways to input to storage anything that has ever been measured or recorded. Again the allure of cheap memory and potential accessibility invites overmeasurement and overbanking of data the customer may never call for, or may access and under- or misuse.

Some fear these new capabilities may foster a culture of conservative engineers and managers, and perhaps even conservative entrepreneurs, if that is not an oxymoron. In business, the ease of re-researching, acquiring, and rapidly processing business data encourages the formation of committees, task forces, and study groups who step through discovery, analysis, and recommendation phases. While they are thus engaged, the competition, like the Scottish farmer, may be fattening its sheep.

How would a person like David Sarnoff behave in today's environment? Would he make the decision to invest millions in color television on the basis of the scant information he then had? Or would he call for extensive technical and market studies, some of which might have delayed or altered the courageous decision he made to proceed?

Another advantage of having lots more data than we once did is the proliferation of ways in which we can combine the data. It is enticing to seek correlations that may or may not exist, when it is so easy to do so. The danger may be that the intuitive spirit may be quelled while the quest for new insight is carried to cautious extremes.

As the ability of more people to acquire and process data increases, the divisions of responsibility and authority may erode. Everyone will be tempted to do jobs other than his or her own. If it becomes so easy to access and process the data to which only the expert was once privy, the temptation to do so may prove irresistible. What an easy way to double-check the accuracy of corporate departments whose recommendations you always suspected, while at the same time finding out whether their boasts about the skills required were exaggerated.

Many people are agreed that half the measurements made in the world today are unnecessary. The trouble is, no one knows which half. Maybe we should form a committee to study this. Of course, they'll need hard data—and some new measurements. . .

Donald Christiansen

TECHNOLOGY 1992

Each year in this issue, *IEEE Spectrum*'s editors and invited experts review many significant products and trends. Two prime examples in this report are porous structures of silicon that emit red, orange, yellow, or green light when illuminated by ultraviolet light from a laser; and a blood gas monitor, small enough to be inserted into a radial artery, that uses optical-fiber sensors and a thermocouple to measure partial pressures of oxygen, carbon dioxide, and hydrogen ion concentration, plus blood temperature, all in real time.

We try to restrict our window of time to about a year—covering principally, for instance, new products introduced within the last six months and anticipating developments that might occur within the next six months. As for the latter, we have in previous reviews forecast the importance of computer-aided tomography, magnetic resonance imaging, and positron emission tomography in medicine; the impact of video disks on consumer electronics; and the blurring of distinctions among microcomputers, minicomputers, and mainframes.

But of course not all highly touted developments sell well. Some innovative products fail for reasons that have little to do with engineering design.

What ultimately determines survival in the marketplace—or indeed, whether or not a product ever reaches the marketplace—relates to factors like standards, regulations, economics, and timing. Problems in any one of those areas are enough to spell the difference between success and failure.

Those considerations are not always spelled out in what follows because space is too tight. But consider just one example. The article on consumer electronics describes, among other developments, the testing process that all candidates for a U.S. high-definition television transmission system must undergo. All the candidate systems are examples of good engineering design, but probably only one will end up as a U.S. standard. The Federal Communications Commission selection of the winner will be based on many considerations. Performance under test is crucial, to be sure, but as is pointed out in this case, equally important are such nonengineering factors as regulatory, legal, economic, and public policy matters.

In reading all of the articles in this issue, you will be exposed to the forefront of technology developments during 1991. It will be interesting to learn in the months and years ahead which of those advances made it and which did not and for what reasons. Chances are the failures will not be due to faulty engineering design but rather to the vagaries of the marketplace. ◆

Ronald K. Jurgen Issue Editor

The July 11 solar eclipse was recorded from an observatory at Mauna Kea, Hawaii, by scientists from camera manufacturer Amber Engineering Inc. of Goleta, Calif., under the direction of astronomers from the Smithsonian Astrophysical Observatory. The imaging system consisted of an infrared camera with a 128-by-128 indium antimonide focal plane array; a video acquisition and processing electronic system; a real-time digital data recorder based on a disk array from Storage Concepts; and a Pro-View system for image generation and enhancement. The disk array recorded every frame of data, but only one in five frames was digitally archived.

Amber Engineering Inc.

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PCs and workstations

- **More of the same: prices fall, performance increases**
- **Line between PCs and workstations blurs further**
- **Is the pen mightier than the mouse?**
- **Multimedia is poised to become major market force**

For personal computer makers, the giddy decade of double-digit sales growth and profit margins ended last year. Indeed, 1991 spelled recession in much of the developed world. Business was certainly dreary for many personal computer makers—including Apple Computer, Compaq Computer, IBM, and many clone makers—who had to cut their prices in the face of tough competition and flat or worse demand. Revenues and profits faltered badly.

In fact, "the whole computer industry was in a price freefall," noted William Bluestein, a senior analyst with Forrester Research Inc., Cambridge, Mass. Overall, the line between personal computers and workstations blurred further as the workstations came down in price [see "Expert Opinion," p. 28]. In addition, networks incorporating both types of machines encroached steadily on minicomputer and mainframe territory.

But PCs did have bright spots. Sales of notebook computers climbed much faster than desktop machines—by 40 percent to US $3.9 billion, according to Aaron Goldberg, a market analyst with International Data Corp., Framingham, Mass. (The personal computer market amounted in the United States, at least, to about $31.5 billion.) Indeed, the number of notebook builders tripled to more than 40 in the course of the year, and is still growing.

A new kind of machine—a pen-based computer—also attracted the market's attention. So did multimedia technology for personal computers and workstations. Some combined the usual text and graphics with digitized voice and music, others added full-motion video, and both astounded observers with their possibilities. A bigger jolt was the announcement that the two biggest rivals in personal computers, IBM Corp. and Apple Computer Inc., were teaming up to create several new products, including computers and a new operating system.

Alfred Rosenblatt Senior Editor

The PC industry matured to the point where the machine became a commodity item and prices declined. Many users, including large corporations, took to shopping around and buying on price alone. Also hastening the decline was the availability of 80386 microprocessors from vendors like Chips & Technologies Inc., San Jose, Calif., and Advanced Micro Devices Inc., Sunnyvale, Calif., which broke the monopoly on the chip of Intel Corp., Santa Clara, Calif.

PEN-BASED COMPUTERS. Those clipboard-sized pen-based machines are reaching for users who find the usual computer keyboard too cumbersome or quite baffling. Instead, data may be entered by hand-printing alphanumeric characters or writing special marks with a stylus, or pen, directly on the computer screen. The screen electronics senses what the pen writes, as well as its location when selecting menu items or icons.

"It could have a tremendous impact on portable and perhaps desktop computers, too," said Egil Juliussen, president of the Computer Industry Almanac, Incline Village, Nev. He envisioned a peripheral on which images could be drawn and which would be attached to the desktop. He also foresaw software being developed to recognize handwriting reliably and the impact of third-party developers writing applications for the machines.

A number of companies either introduced such computers in 1991 or announced they were developing them. These companies, including Momenta, NEC, NCR, Samsung, Sanyo, and IBM, joined others like GRiD Systems Inc., Fremont, Calif., and MicroSlate of Montreal, which have been selling such computers for a couple of years. From about 40 000 sold in 1991—some 75 percent by GRiD Systems—market analyst Bluestein looked forward to annual billion dollar markets quite soon. He estimated sales would climb to 150 000 units this year, 240 000 in 1993 and 905 000 in 1995.

HIGHLIGHTS

Success: Sales of notebook computers boomed amid a worldwide recession.
Shortfall: The PC market turned flat and earnings of the likes of Compaq Computer Corp. and Apple Computer Inc. plunged.
Notable: Newly introduced 2.5-inch disk drives moved from 20 MBytes capacity to 120 MBytes in less than a year.
Newsmaker: Manufacturers lined up with pen-based computers for users put off by a keyboard.

Generally, the platforms weigh 2.25–2.75 kg and rely on a backlit or reflective liquid-crystal display. Selling prices range from $4000 to $7000, depending on the amount of memory and other details.

They are built around the Intel 80386SL microprocessor chip and rely for nonvolatile memory on a 20- or 40-MByte 2.5-inch hard-disk drive or the relatively new solid-state memory card built to standards set by the Personal Computer Memory Card International Association (PCMCIA).

Scheduled for release early this year are the two operating systems that seem destined to slug it out for market supremacy. They are being developed especially to accommodate the functions of pen-based computers. One system, Pen Windows, comes from that venerable software vendor, Microsoft Corp. of Redmond, Wash. The other, Penpoint, is from a software startup, Go Corp. of Foster City, Calif. The systems are quite sophisticated. Penpoint, which supports Intel chips, is a 32-bit, object-oriented, general-purpose operating system compatible with DOS files.

The pen is the means with which to "navigate" through a database. These devices do far more than convert alphanumeric characters printed by a user into ASCII (American Standard Code for Information Interchange) code. An X quickly drawn over a word deletes the word. A circle around a word may highlight it, and turning a page requires only a tap of the pen on the proper icon. With such gestures, and with pulldown menus and the right application software, a user can create and edit reports about as readily as with a keyboard. (And just in case, Momenta has a pen-based model with a keyboard.)

First applications are tailored to specific users. Delivery and route sales people are using the computer to call up order forms. Printing an account number prints out such information as name, address, and ship-to and bill-to addresses in all the right boxes on the form, which is now ready for merchandise orders or deliveries to be entered. Writing in a part number summons its description. Inserting a quantity calls up the unit price and calculates total price.

IC CARDS. Those relatively new credit-card-size IC cards also got a boost last September when the PCMCIA trade association came out with version 2.0 of its memory card standard. This release of the standard adds a specification for plug-in I/O cards. These are the same size as the IC cards and contain a complete expansion peripheral.

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If the goal is to build a half- or one-kilogram notebook or palmtop computer, "you must go to a memory card to get rid of the heavy batteries needed to power a hard disk," noted Daniel Sternglass, president of Databook Inc., Ithaca, N.Y., a supplier of IC card drives, interface circuits, and system software. "And now, with the I/O card, you can keep the computer simple and add plug-in slots to accept almost any function normally provided on an expansion card for a desktop—including a modem, network adapter, fax, or a controller for a hard disk."

Several manufacturers, including AT&T, Sharp, and Toshiba, showed notebook computers with memory and I/O cards at the Fall Comdex Show in Las Vegas.

MULTIMEDIA BLOSSOMS. Multimedia is another technology that analysts believe is just a few years away from boosting workstation and personal computer sales. With multimedia programs, these machines will be able to handle files of sound and full-motion video images as easily as they now handle text. The computers will play voice and music in high-fidelity digital-audio stereo and will show movie-quality images.

Adoption of standards, and multivendor announcements of systems, marked the emergence of the field. A number of hardware and software vendors gave their backing to the development of standards for multimedia so that applications could "play" across a range of hardware platforms. The Interactive Multimedia Association brought together 170 such companies, including Apple, Compaq, Digital Equipment, and IBM. Their goal is to produce a common file format that will enable applications to work across IBM PCs and compatibles, Macintoshes, reduced-instruction-set computer (RISC) systems, and networks.

Multimedia PC is the name taken by another group of companies, led by Microsoft and Tandy Corp., Fort Worth, Texas. They

EXPERT OPINION: PCs and workstations blend new kinds of applications

FOREST BASKETT

For several years, the computer industry has debated the distinctions between PCs and workstations. Today, the question is no longer relevant: what is important is what the system can do.

Computing technology, in terms of memory density and central processing unit speed, is advancing at a rate of about 60 percent a year. This pace means that new capabilities are constantly coming on the market at affordable prices. As a result, systems for the 1990s will give users new tools for enhancing productivity, gaining insight into data, and finding new ways to do their jobs.

The decade's first desktop computers, incorporating the latest technologies, are beginning to offer users the power to run sophisticated applications; to combine three-dimensional graphics and images; to add compact-disc-quality sound and video to applications; and to share more information throughout even a geographically dispersed organization.

'The ability to blend artificial and real worlds presents possibilities for fields as varied as entertainment, geosciences, and medical imaging.'

Increased processing power is at the heart of new system capabilities. Reduced-instruction-set computer (RISC) chips will be the central components of high-performance PCs and workstations, enabling the implementation of other new technologies. At the same time, multiprocessor RISC systems are on the increase. While these systems currently fall in the high-end workstation category, in the next few years they will become part of standard computing environments as software for them is developed and as opportunities for applying multiprocessing technology expand.

With greater processing power and dramatically improved system bandwidths, desktop systems are also bringing together 3-D graphics and imaging, with exciting results. Pixels can be moved and changed quickly on screen—an essential for computer graphics and image processing. With this technology, users can combine the products of their imagination with real scenes and images. They can overlay graphics on video frames viewed on their computers, and output the results back to video.

The ability to blend artificial and real worlds presents possibilities for fields as varied as entertainment, geosciences, medical imaging, scientific visualization, and others. In France, for example, a children's television show today features real-time computer-generated puppets—controlled by "puppeteers" wearing data gloves—interacting in live scenes with human characters. With graphics and imaging technology becoming more affordable, imagination alone will limit the creation and proliferation of inventive applications.

What is sometimes called multimedia is part of this trend. Desktop systems are enabling vendors to include audio and video in their applications—and are including these capabilities among their standard features. Enhanced processing power then allows users to add these elements to traditional documents, presentations, or even technical and scientific applications. Computer programmers, for example, could teleconference from their desktop systems and discuss their work with colleagues.

While multimedia itself is not the separate business many claim it is, the fundamental technologies involved may offer ways to simplify tasks not previously considered computing problems. Much of today's innovation is focused in this area of graphics, imaging, video, and audio. With the costs of such technologies as high-quality audio or video decreasing rapidly, the appeal of systems with these talents will become as compelling as color screens.

Another key opportunity for 1990s' computing is the ability to link scattered systems in coherent computing environments, letting users cooperate on projects and share information much as they would if linked to a single mainframe. Networking and data compression technologies are advancing to the point that users of desktop systems can begin to share nontraditional data types such as audio and 3-D graphics as well as text. Fiber optics is also making long-distance, high-speed networking feasible, expanding the limits of what can be called a coherent computing environment. These types of environments, consisting of multiple workstations in various locations, open up exciting possibilities for sharing work and accomplishing tasks in large organizations. With their aid, desktop systems should be able to provide supercomputing-on-demand without traditional supercomputers.

Some industry watchers forecast a computer industry shake-out. Yet the idea of industry consolidation would make sense only if technological progress were slowing. In fact, however, we are in a "technology push." In the midst of this rapid change, successful companies will be those that innovate and adapt, and bring new capabilities to market quickly. Traditional companies, unable to move and change as fast, may have difficulty remaining competitive.

As old notions of PCs and workstations fade and new capabilities move to the desktop, technology companies will have to choose: they can cling to dogmas or move toward the future—but they will not be able to do both. Users, for their part, will look increasingly at capabilities in choosing next-generation computers, rather than at traditional system definitions and distinctions.

Forest Baskett is senior vice president of R&D for Silicon Graphics Inc., Mountain View, Calif. Earlier, he was director of Digital Equipment Corp.'s Western Research Laboratory, where he spent four years designing and building research prototypes of RISC systems. He has also been a professor of computer science and electrical engineering at Stanford University, California.

have agreed on standards and are marketing products with speech and music, as well as text, graphics, and still images.

Microsoft also belongs to IMA. So does Intel, whose new ActionMedia II plug-in boards and software for full-motion video [see photograph] won the "Best of Show Award" for multimedia products at the Comdex Show. Other companies have developed software systems for compressing full-motion video so it can be stored in far less space, and chips to provide real-time decompression of full-motion video.

WORKSTATION VOLUME UP. Workstations fared better than personal computers in 1991, with unit shipments up about 34 percent compared to 1990, estimated Laura Segervall, a senior industry analyst at Dataquest Inc., San Jose, Calif. But though the growth is double-digit, it is well below the 50 percent growth enjoyed between 1988 and 1989. Sales in 1991 should hit $8.7 billion, up from $7.4 billion in 1990, Segervall said.

As did personal computers, workstations also saw price cuts. Sun Microsystems Inc., Mountain View, Calif., was at the forefront here as it tried to remain No. 1 in workstations and the leader in low-cost workstations. One of the new Sun machines, for example, the Sparcstation ELC with a list price of $4995 has 1½ times the speed and four times the memory of its predecessor, the $6995 Sparcstation IPC. Another, the Sparcstation IPX, at $11 995 is 25 percent cheaper than the older Sparcstation 2 it resembles.

However, Hewlett-Packard Co. and others were not only challenging it in terms of price but were also edging Sun aside in speed. HP introduced its HP Apollo 9000 Series 700 workstations—based on HP's Precision Architecture-RISC—with price performance that surpassed machines from Sun, Digital Equipment, and IBM.

Another mark in workstations was made by Silicon Graphics Inc., Mountain View, Calif., which brought three-dimensional graphics to the workstation world for under $10 000. The Iris Indigo workstation, built around a 33-MHz R3000A RISC microprocessor from MIPS Computer Systems Inc., Sunnyvale, Calif., also delivers multimedia capabilities—with 16-bit digitized audio included and full-motion video an option. Base price is $7995, with 8 MBytes of memory and a 16-inch color monitor.

The station delivers 30 MIPS and 26 SPECmarks and offers Silicon Graphics' highly regarded IRIS Graphics Library to users and applications developers [see Graphics, p. 16].

APPLE, IBM ALLIANCE. The agreements between IBM and Apple Computer, in which Motorola Inc. also plays a key role, incorporate five hardware and software initiatives. Three expand the companies' current technologies, while two focus on the creation of new technologies.

First products will ease the integration of Macintosh personal computers into IBM networks of mainframe, midrange, and departmental computers. They were to be available as soon as last month. Also, a new family of more powerful RISC microprocessors will be derived from IBM's well-regarded chip set in its RISC System/6000 workstation. The PowerPC chips, to be designed in Austin, Texas, by Motorola and IBM engineers, are destined for future Macintosh and IBM personal computers. They will be manufactured by Motorola, which will also sell them to the industry.

Still another project involves an open-systems platform, PowerOPen, derived from AIX, IBM's version of the Unix operating system, the Macintosh interface, and the Power RISC architecture. The goal is to enable a system to run Macintosh and AIX applications on RISC-based hardware from both companies [see "Software," p. 30.] The last two developments are said to be two to three years off.

IBM and Apple also formed an independent company to create and license multimedia technologies. Another independent joint venture is to develop object-oriented software for a "next-generation operating environment." Again, this technology will be licensed widely, and both companies intend to use it in future products: Apple in Macintosh, and IBM in its OS/2 and AIX operating systems.

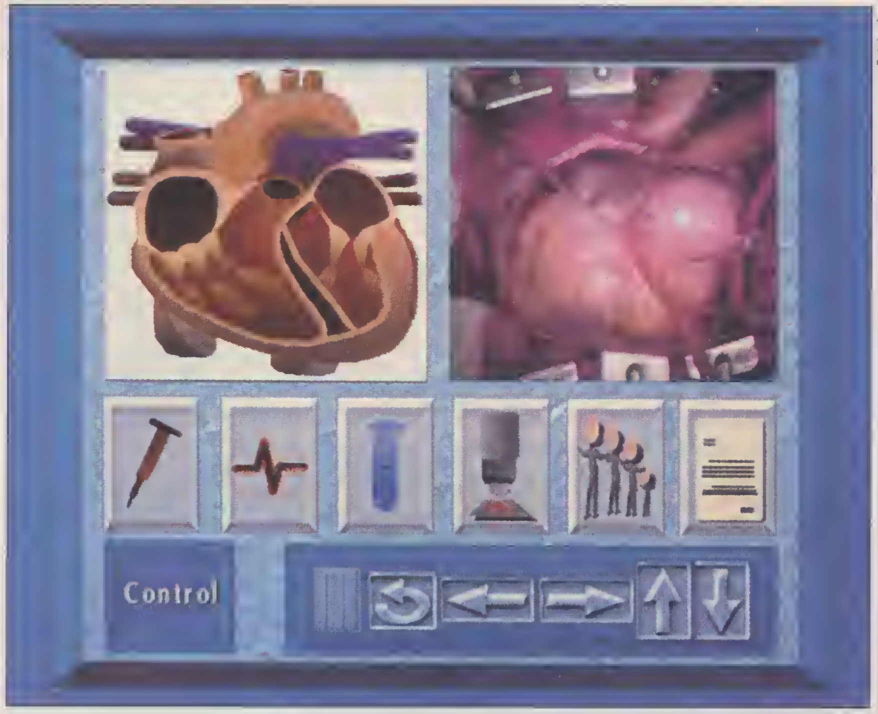
ON THE DISK DRIVE FRONT. The relatively new 2.5-inch drives came amazingly far and fast last year. Demand, fueled by the need of laptop and notebook computers for the drives' small size, zoomed quickly.

From a 20-MByte start, manufacturers were soon selling drives of 40 and 60 MBytes and higher capacities, and prices fell. Conner Peripherals Inc., San Jose, Calif., the market leader, now has an 85-MByte drive and Fujitsu Inc. unveiled a 90-MByte model. But the capacity battle did not end even here. At the Comdex Show, Conner said it was making available evaluation quantities of a 120-MByte, 2.5-inch, dual-platter disk drive in a full-height form factor, and that a 540-MByte, six-platter disk drive was under development. That's a half gigabyte of memory, which means that 2.5-inch disk-drive technology may not be just for notebook computers any more.

Robert H. Katzive, vice president of Disk/Trend Inc., a Mountain View, Calif., market researcher, estimated that 3.9 million 2.5-inch drives of all capacities would be sold in 1991, up from 847 000 the year before. Next year, he predicted, 7.6 million units would be sold, reaching almost 17 million units in 1994.

Thus, while 2.5-inch drives climbed, 3.5-inch drives were reaching a peak, albeit at a higher level. Katzive sees the peak reaching 25 million units in 1992, up from 23 million in 1991, followed by a decline to 21 million units in 1994.

But still smaller drives are also being thrown into the mix. For example, Integral Peripherals Inc., Boulder, Colo., last year shipped 1.8-inch disk drives with 20 MBytes of capacity. They are being embedded within "companion-size" notebooks. These measure 15 by 25 cm (instead of the notebooks' roughly 22.5 by 28 cm), weigh 1–1.5 kg. (instead of 2–4 kg), and have a keyboard only 70–80 percent the usual size. Integral Peripherals promises to have 40-MByte drives during the first quarter. ◆



Datalus Inc.

Demonstration for training doctors, based by Datalus Inc., Okemos, Mich., on Intel multimedia boards, couples video of heart surgery to a heart animation. Icons (from left) call up patient's medication levels, electrocardiogram, blood levels, tissue samples, and case history.

Software

- **New Windows applications dominate marketplace**
- **Battles loom in RISC for the desktop**
- **Object-oriented programming and C++ gain ground**
- **A push for software standards and metrics**

Whereas computer companies' revenues shrank, software companies did particularly well last year. Cost competition in personal computers and workstations has allowed more companies to purchase new hardware at rock-bottom rates, and this has fueled demand for better operating system and application software.

U.S. companies dominate software, while the once-unbeatable U.S. computer hardware companies battle stiff competition from the Far East. To regain control of their destinies, hardware companies last year tried to have more input in determining software's direction, either by allying with strong software companies or by trying to retake the software lead on their own.

BATTLE TACTICS. Early in 1991 the relationship between Microsoft Corp., Redmond, Wash., and IBM Corp. formally disintegrated. IBM took on full responsibility for the future of OS/2, and Microsoft went on building on its Windows lead, although it agreed to continue development of a portable version of OS/2.

In the spring Microsoft became part of the startup Advanced Computing Environment (ACE) Consortium, which is committed to the support of applications that run under Windows and OSF/Unix. Initially consisting of Compaq Computer, Digital Equipment, Microsoft, MIPS, and the Santa Cruz Operation (SCO), the group endorsed MIPS' reduced-instruction-set computer (RISC) architecture. Compaq and Digital will use it to build next-generation personal computers that run both Microsoft Windows and SCO's Open Desktop/Unix OS.

Then in the summer, Apple Computer Inc., Cupertino, Calif., and IBM announced their intent to jointly develop and market new technologies, and spent the rest of the year filling out their strategy. Their plans call for two joint ventures: one for system hardware called Kaleida, and another for software called Taligent. The hardware company would be using a low-cost chip developed by Motorola Inc., Schaumburg, Ill., on the basis of IBM's RS/6000 RISC architecture.

Richard Comerford Contributing Editor

If the Apple-IBM joint ventures are approved by the U.S. government's antitrust people, the two companies that have set the standards in the PC market will have Taligent develop Power Open, an advanced operating system (OS) based on Apple's work on a portable OS code-named Pink. Power Open would run on Kaleida's platforms, accepting applications designed for the Macintosh OS, DOS, Windows, and Unix. Even without any legal hitches, though, the Apple-IBM software worlds will probably not come together in full product form until the mid-'90s.

But IBM will support both RISC and complex-instruction-set computer (CISC) architectures. In November, the company signed a 10-year pact with Intel Corp., Santa Clara, Calif., to jointly develop technology for future generations of the 80X86 CISC architecture, which will integrate most computer functions and probably become the basis of highly portable systems. The agreement also gives IBM the right to manufacture versions of the future chips.

So in 1992 the main weapons in the PC OS battle will be the reincarnations of Windows and OS/2. IBM had planned to have OS/2 Version 2.0 ready in time for the December sales season, but has had to push back the date until spring. At that time, a revamped OS/2 will have to contend with a new version of Windows and the first fruits of the ACE Consortium.

A thread that runs through the competing activity on desktop operating systems is Unix; ACE and Apple-IBM are planning for it. Certainly IBM will support OSF Unix from the top of its line to the bottom; last year, the company announced that it intends to produce a version of AIX for its mainframes to ensure their role in its Enterprise Wide Systems. And some companies that once solely supported DOS are now moving to Unix; in computer-aided engineeering (CAE), OrCAD's porting of its tools to Unix is a prime example.

HIGHLIGHTS

Success: For the second year, Windows proved to be the most important factor in personal computer software, boosting revenues for software retailers in a recessionary market.

Shortfall: IBM Corp. had to reschedule release of its much-heralded OS/2 2.0 from last fall until the spring of 1992.

Notable: Mentor Graphics Corp. delivered its delayed Falcon framework, which early reports seem to indicate is living up to its promises.

Newsmakers: Apple Computer Inc. and IBM agreed to jointly develop a next-generation operating system for personal computers, as well as the computers themselves.

WINNERS. Whether or not all the commitments made by these companies are kept, users will be sure winners. If IBM's claim that OS/2 2.0 will run Windows applications better than Windows turns out to be true, then users who have already invested in Windows applications will get a power boost by switching operating systems; they will not have to worry about losing their application investment. If it is not true, they will be no worse off than they are now.

So both software developers and users felt confident about continuing to invest in Windows applications. Not only did Windows 3.0 installations exceed six million, but sales of Windows applications kept software sales growing at a rate of over 15 percent. And dealers could not keep their shelves stocked with Microsoft's latest incarnation of DOS—V5.0 introduced in June—which gives a power boost to Windows.

For engineers, a wealth of new programs came out under Windows 3.0. Among the more interesting were an automated software quality checker called SQA:ROBOT from Software Quality Automation, Lawrence, Mass.; a Windows application development package called Toolbook from Asymetrix Corp., Bellevue, Wash.; Simulab, a new model-building and simulation tool from the MathWorks Inc., Natick, Mass.; the LapCAD finite-element modeler from Lapcad Engineering, San Diego, Calif.; and Winix, from Winix America, Portland, Ore., a Unix-like package that runs under Windows to provide network and communications services and expand PC storage by using a Unix server as a virtual disk.

The graphics capabilities of inexpensive systems now make it possible for virtually anyone to use visualization—that is, the rendering of data in three-dimensional forms that give the viewer a better feel for its significance. For example, consider recent offerings from Champaign, Ill.-based Wolfram Research Inc. and IMSL, Houston, Texas. Wolfram began shipping a Windows version of Mathematica 2.0 last summer, putting visualization of complex mathematical formulae on PCs. With IMSL's Exponent Graphics, a Fortran tool, engineers can view

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electrical-field equations as 3-D images. [See also *IEEE Spectrum*, November 1991, pp. 34–37.]

Another company, Stardent Computer Inc., Concord, Mass., tried to dominate the visualization market with its Application Visualization System (AVS) by porting it to several popular workstations. But with Stardent's hardware-related money problems, AVS support was moving to the AVS Institute at the University of North Carolina, Chapel Hill, at year-end.

CAE AND CASE, BRIEFLY. *Spectrum*'s recent special focus report on computer-aided engineering (CAE) [November 1991, pp. 21–68] revealed a great deal of activity in this area. But because of the general slowdown in the economy, it was not a particularly profitable year for CAE companies.

Mentor Graphics Corp., Beaverton, Ore., made good on its promise to launch its Falcon framework to which many CAE vendors have committed their support [*Spectrum*, January 1991, p. 39, and November 1990, pp. 90–92]. Nonetheless, it was forced to cut staff across the board and retrench on its computer-aided software-engineering (CASE) activities. The merger of two San Jose, Calif.-based CAE companies—Cadence Design Systems Inc. and Valid Logic Systems Inc.—while strategically sound, also signaled the need for consolidation to underwrite heavy development costs.

For CASE, the year got off to a good start when Informix Software Inc., Menlo Park, Calif., announced its OpenCase program in January. The goal: to provide tools for DOS and Unix platforms that will work together, even though they come from different tool vendors. Thus, for the first time, software developers will be able to choose tools in terms of their individual merits, not compatibility issues. Cadre Technologies Inc., Beaverton, Ore., and Saber Software Inc., Cambridge, Mass., joined the nine-member group in August.

While vendor groups tried to create *de facto* standards, much work was also being done to realize *de jure* ones. Late last year, the IEEE Computer Society's P1175 working group released a Trial Use Standard reference model. It will be used for one year and, if it works as a model, be promulgated as a formal standard in 1993.

Another area of CASE that will receive more attention this year is software metrics: the measurement of all factors contributing to software performance during its life cycle. Last year metrics of the function-analytic generation—with concentration on such

EXPERT OPINION: In search of simpler software integration

WAYNE H. WOLF

This year will see system integration becoming easier in some respects and harder in others. It will be easier, because the escalating war of competing architectures that is driving workstation prices down is also forcing a kind of unification of software environments (something Unix programmers have long hoped for).

Warhol's Law of Computer Architecture ("Every architecture will be the price-performance leader for 15 minutes") encourages buyers to switch computer vendors regularly. So to entice a potential buyer to their architectures, hardware vendors improve their operating systems to simplify porting of his application programs.

On the other hand, it will be harder, because Unix, DOS, and Macintosh operating systems must work together. Many projects use all three at some stage because each provides some unique software, and none will disappear in the immediate future. In the short term, system integrators and users will just have to become even better at making these very different platforms communicate smoothly. For the longer term, the new wave of alliances—Windows running on MIPS processors, Unix running on Macintoshes with IBM CPUs—will introduce both opportunities and obstacles for mixing and matching software tools.

'It makes much more sense for CAD companies to develop many small application-specific frameworks than to build a single universal framework. Big frameworks are hard to change and, like dinosaurs, prone to extinction!'

Object-oriented remains the key adjective for programming technology. While object-oriented languages do not solve every programming problem, they do help good programmers design modular, reusable software.

C++ is the favored object-oriented language for many electronics applications because it is a superset of the familiar C language. Up to now, C++ has lacked two key features: templates and exception handling. Templates allow, for example, a programmer to write one parameterized description of a list, which can be specialized to provide type-safe lists of strings, icons, and so on. Exception handling provides mechanisms to match error conditions with error handlers at run time, rather than compile time, giving more robust error recovery and better information to the user.

According to AT&T's Bjarne Stroustrup, the originator of C++, implementations of templates should be available by this month and exception handling will be added by the end of 1992.

Object-oriented databases go hand in hand with object-oriented languages—they provide database functions such as transaction locking and query languages for objects. That suits them especially well to many engineering applications: objects and inheritance describe many engineering designs, and object-oriented databases let the applications use the program data structures directly as a database. Expect to see continued adoption of object-oriented databases over the next year.

I believe that the growing availability of general-purpose programming tools may, in the long run, replace monolithic computer-aided design (CAD) frameworks with a loose collection of CAD utilities and tools.

The reason is that a CAD framework supplies essentially four things: general-purpose programming utilities, user-interface utilities, a database for design information, and CAD-specific utilities. In the long run, CAD companies cannot compete with software tools companies, which have much bigger markets and so can be more innovative.

Generic user-interface programming tools make it easy to build custom interfaces, which obviates the need for the CAD framework's interface toolboxes. Object-oriented programming languages allow users to customize utility functions for their specific requirements.

That leaves the CAD-specific design representations and CAD-specific utility algorithms for a CAD framework. It makes more sense for CAD companies to develop many small application-specific frameworks than to build a single universal framework. Big frameworks are hard to change and, like dinosaurs, prone to extinction!

Consider the desktop publishing market. Far from stifling innovation, DOS's lack of uniform, centrally administered standards actually encourages the rapid invention of new tools and helps lower costs. Popular programs' file formats become *de facto* standards; other companies design new programs that add value; and increased competition helps lower prices.

Such a patchwork of *de facto* interface standards makes even more sense in CAD. A circuit simulator and high-level synthesis system may use the same general programming utilities, but they share relatively few CAD-specific algorithms. Having many small, *ad hoc* frameworks for layout, simulation, logic optimization, and so forth, may give designers more tools from which to choose, more freedom to mix and match, and speedier development of support tools.

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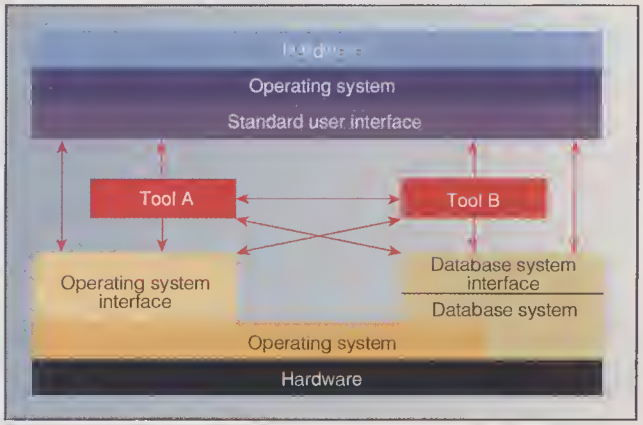
things as process maturity, reliability, failures, and faults—has been applied with great success. This is pushing metrics into the business-directed generation, where technical quality, coverage of user needs, and top-down and bottom-up traceability are major concerns.

PROGRAMMING'S ORIENTATION. Object-oriented programming (OOP) continued its ascent among commercial programming paradigms in 1991, gathering more tool support from many vendors. Most of this support centered on C++, which C programmers find easier to learn than other object-oriented languages. Oasys, Lexington, Mass., spread the popular Green Hills C++ onto RISC workstations from IBM, Digital, and Mountain View, Calif.-based Sun Microsystems Inc. Meanwhile, SunSoft Inc., Sun's software subsidiary, signed a volume purchase agreement with Saber Software for Saber C++, a workstation-based C++ programming environment.

Other companies unveiling object-oriented products included Network Integrated Services Inc., Santa Ana, Calif., which brought out Meijin++, the first library for developing mathematical, statistical, and queuing models in C++ and studying their behavior through simulation runs. Rational, Santa Clara, Calif., introduced Rose, a new analysis and design tool that supports the Booch method of object-oriented development to simplify code reuse, and provides an object repository in a client/server environment. Mark V Systems Ltd., Encino, Calif., known for its Ada tools, introduced the ObjectMaker analysis and design tool, which generates C++ code from detailed design diagrams or uses existing code to reverse-engineer a project.

Database support increased as more object-oriented applications came online. For instance, Ontos Inc., Burlington, Mass., shipped Release 2.1 of its object database, rewritten for a distributed environment. The company made a point of thoroughly testing R2 to give it "industrial strength," because its customers were moving C++ applications from development to deployment. In a related move, Object Design Inc., Burlington, Mass., and Saber Software integrated their respective object-oriented database and C++ programming environment packages so that users could employ object libraries in creating large-scale, data-intensive applications. Interbase Software, Bedford, Mass., also added object support to its relational database.

There were moves, too, to standardize on schemes for sharing and using object-oriented information in distributed computing environments—networks of computers from different vendors. Hewlett-Packard, NCR, Object Design, and Sun Microsystems joined forces to propose an Object Request Broker (ORB) standard to the Object Management Group, an international OOP group. Using Sun and HP distributed Object Management Facilities and its Class Definition Language (CDL), NCR would provide a CDL compiler with an interface to the firm's Remote Method Invocation (an object communication technique). Object Design would implement the ORB interfaces to its Object database management system.



Last year the IEEE Computer Society's working group P1175 released a set of reference models for use as a Trial Use Standard for developing future CASE standards. The model for platform environments, shown here, covers multiple as well as single hardware platforms. In it, the tool interface considerations are delineated; tools can interact with the standard user interface, the operating system (OS) of the platform on which they run (maybe the same as the user interface OS, but shown separately for clarity), a database, and other tools.

C++ ALTERNATIVES. While C++ is quickly becoming the *de facto* standard for object-oriented programming, there are still some interesting rivals. The European Community's Esprit II Business Class project has bypassed fourth-generation languages in favor of object-oriented Eiffel to create CASE tools for business application development. Considered a "pure" object-oriented language, Eiffel introduced the concept of exception handling to OOP. Last year, Interactive Software Engineering Inc., Goleta, Calif., and Quarried Software, Newport News, Va., brought Eiffel, including development tools and class libraries, to the NeXT platform so it will get high visibility in a number of university CASE projects.

One place where C++ will not find support is the U.S. Air Force. On July 9, 1991, the service released the results of a study to determine under what circumstances a waiver to Department of Defense (DOD) Ada requirements might be granted to allow use of C++—for example, in the DOD's Corporate Information Management program. The conclusion: none. Entitled "Ada and C++: A Business Case Analysis," the study will be used to support the development of DOD programming language policy for information systems and command, communications, and control systems.

While C++ showed advantages over Ada in its compile time and run-time efficiency—and of course in support for object-oriented design—it was found to be relatively weak in support for large-scale program development and reliability assurance. It was estimated that C++ was three years behind Ada in maturity and tool support, and that a stable, standardized version of C++ would not be available until 1994. On the other hand, Ada 9X, due for promulgation in 1993, will add object-oriented support, and it is believed that hardware and compiler improvements will overcome Ada's run-time and compile disadvantages.

ADA LIVES. There was no lack of activity in Ada compilers in 1991. By mid-year, the number of new ones validated for conformance to DOD standards (286) was almost equal to the previous full-year high (292 in 1989), after a noticeable slowdown in 1990. There are now validated Ada compilers for every popular workstation and personal computer. In August Meridian Software Systems Inc., Irvine, Calif., alone added eight RISC computers to the list of platforms it supports with Ada compilers.

In the spring, Sun unveiled the Sun Ada Development Environment, which uses a compiler from Verdix Corp., Chantilly, Va., and Sparcworks/Ada, a suite of programming tools with the Open look graphic user interface. Telesoft introduced an Ada development environment for Sparc-based RISC workstations in June, following its April announcement of tools that automatically generate OSF/Motif and X-Windows System graphical user-interfaces for Ada applications, letting Ada be used with those widely accepted interface environments.

To help its member companies in the development of large, real-time Ada software systems, the Software Productivity Consortium, Herndon, Va., licensed Mark V to develop an extension to ObjectMaker for the Consortium's Ada-based Design Approach for Real-Time Systems.

The universal need for such software is reflected in an International Data Corp., Framingham, Mass., prediction that real-time embedded system markets will double from 1989 to 1994, from US $3.4 billion to $6.7 billion. The research company also reported that business for vendors of real-time operating systems and development environments is growing even faster.

Not surprisingly then, 1991 saw one of the leading vendors, Wind River Systems Inc., Alameda, Calif., actively pursue the most popular platforms. In April, to VxWorks—its real-time operating system and development environment—it added support for the MIPS 3000 to that for Sparc and i960 RISC chips; in September, it added the Motorola MC68040 and HP X stations. ◆

Large computers

- ***Highs and lows at Unisys***
- ***Posix is the one***
- ***Super year for supers***
- ***Massive parallelism rules***

In the market for large computers, 1991 was a year of technological highs despite financial lows.

It was a year when: a powerful mainframe with an innovative super-scalar architecture made its debut; almost all U.S. makers of large computers committed themselves to some form of massive parallelism; and the first supercomputer-class machine with gallium arsenide processors was introduced (and it was not the long-awaited Cray-3).

It was also a year when even IBM Corp., the industry's seemingly invulnerable stalwart, reported steep losses (including an 84 percent drop in third-quarter earnings), trimmed 20 000 workers from its force of 373 000, and went through an uncharacteristically public period of corporate soul-searching. Similar problems also made 1991 a year to forget at Digital Equipment, Groupe Bull, Olivetti, and many other Western makers of large computers. In Japan, however, Fujitsu, Hitachi, and NEC were shielded from the worst of the troubles, mainly by a still expanding domestic market.

UNISYS: A MICROCOSM. If one company exemplified the large-computer industry's highs and lows, it was Unisys Corp. The Blue Bell, Pa.-based company was forced to sell off roughly US $250 million in assets as it struggled under debts of $3 billion. It also accelerated its attempts to reduce its workforce below 70 000—down from 120 000 in 1987, shortly after Burroughs Corp. and Sperry Corp. merged into Unisys.

At the same time, the company brought out a high-end mainframe computer featuring one of the most advanced architectures in its class. The A19, which made a low-key debut on March 6, is configurable around one to six emitter-coupled logic central processing units (CPUs). Unisys says the A19 machines perform about on a par with the IBM 9021-820/900 mainframes, but are much smaller and air-cooled, thus using one-seventh to one-third the power of the water-cooled IBM mainframes.

Each A19 CPU consists of four distinct subunits for specific functions, such as executing arithmetic instructions, evaluating virtual and physical addresses, and transferring data to and from main memory. The fourth subunit, or code unit, is linked to one of the A19's most intriguing features—its ability to manipulate the code stream produced by the compilers so as to execute instructions in parallel and in an order other than the one in the code stream.

Glenn Zorpette Senior Associate Editor

The code unit can "look" far ahead into the stream, examining data dependencies between instructions and searching for opportunities to group as many as six into a single "super" operation executable in a single clock cycle by one of the other subunits. Such tricks and others let the A19 keep pace with IBM mainframes that operate on a fourth of the A19's 38-ns cycle time.

Unisys also introduced a high-end machine in its other mainframe line, the 2200 series, which originated in Sperry's Univac 490 computer (the A19's ancestry can be traced to the Burroughs 5000). Although the two mainframe types have utterly different architectures and instruction sets, Unisys says it has merged development operations for IC packaging and system manufacturing in the two lines; overall, three-quarters of the components in the machines were developed in common procedures, according to the company.

Still, carrying two lines remains a financial burden for the company. "They're starting to converge the technology base, but their problem is they're still supporting two completely different software architectures," said James L. Cassell, vice president for large computer strategies at the Gartner Group in Stamford, Conn.

New machines were announced by most other mainframe makers, too. In September, IBM filled out the middle of its ES/9000 (Summit) mainframe line with four water-cooled and three air-cooled models. Control Data Corp., Minneapolis, Minn., also came out with some middle-range mainframes, the Cyber 972 and 974. NCR Corp., Dayton, Ohio, unveiled a high-end machine, the System 3600, which, the company claimed, offers peak processing rates of up to 2000 million instructions per second (MIPS)—several times the rate of current high-end mainframes. NCR, which was acquired by AT&T Co. in September, expects later this year to introduce the System 3700, the long-awaited top-of-the-line. "They're betting their bippy on that machine," opined one mainframe analyst, who asked not to be identified.

HIGHLIGHTS

Success: Convex Computer Corp. unveiled the first supercomputer with processors based on gallium arsenide integrated circuits.

Shortfall: Virtually all makers of large computers suffered steep financial losses or declines in earnings.

Notable: IBM, Cray, and Digital Equipment committed themselves to offering a massively parallel computer in the near future.

Newsmaker: IBM chairman John F. Akers announced a potentially far-reaching reorganization of his company.

But beyond the obvious trends (what Cassell and others sum up as "cheaper, smaller, faster, larger"—cheaper prices, smaller footprints, faster processors, and larger memories) two more profound tendencies became clear in these and other new computers. First, most will be able to run programs under a version of the Unix operating system (the Control Data machines, on the other hand, have optional hardware and software enabling them to exchange data in a so-called open environment, in which different vendors' products work together).

POSITIVELY POSIX. In most cases, the mainframes do not run Unix directly (a "native Unix" environment). Instead, they run modifications of their own proprietary operating systems that comply with Posix, an IEEE standard for open computing. Posix compliance "has become mandatory for the 1990s, and the vendors are committed to it," said Cassell. At its Sept. 11 announcement, for example, IBM announced not only Posix compliance but also a native Unix offering—its first for a mainframe—which was basically an enhancement of its Advanced Interactive Executive (AIX) operating system.

A MASSIVE TREND. The second trend that became clear last year was the move toward massive parallelism. The technology has been commercial for some time—Thinking Machines Corp. has been peddling its Connection Machine since 1987, for example. In late October, the Cambridge, Mass., company unveiled the latest-generation Connection Machine, the CM-5, which lets users program in either data-parallel or control-parallel styles [see "Expert opinion," p. 34]. Each node in a CM-5 (there can be up to 16 384) is based on a reduced-instruction-set scalar computer and four vector pipelines; peak performance per node is 128 million floating-point operations per second

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(megaflops), according to Thinking Machines.

What was notable last year was that virtually all established, mainstream makers of large computers committed themselves to having a massively parallel offering available by 1995. (NCR has a head start in this arena—its System 3600, for example, is based on up to 288 Intel 486 microprocessors.)

IBM and Digital Equipment Corp., Maynard, Mass., apparently concluded that the fastest way into the arena was by allying themselves with younger, smaller companies with relevant expertise and available products. DEC's new DECmpp 12 000 systems, for example, are essentially a repackaging of hardware from Sunnyvale, Calif.–based MasPar Computer Corp., outfitted with DEC software for open computing and networking, and with DEC workstations as front ends. These $240 500–$1 502 500 machines can be configured with 1024–16 384 processors. Peak performance is 1.2 billion floating-point operations per second (gigaflops), or 26 000 MIPS, according to DEC.

IBM's venture, on the other hand, was much less defined at presstime. Late in September, the company announced it had reached a technology-exchange agreement with Thinking Machines Corp., which has been one of the leading lights of massive parallelism since the company's inception in 1983. The main goal of the agreement appeared to be developing hardware and software so that IBM's mainframes may work in tandem with Thinking Machines' computers. Though few details were released, Thinking Machines will also reportedly gain access to IBM's semiconductor and disk-drive technologies.

In a financial report, Cray Research Inc., Eagan, Minn., confirmed it is at work on its own massively parallel system, a multiple-instruction, multiple-data (MIMD) design, with a projected peak performance in excess of 100 gigaflops. And in a memo, Cray chairman John A. Rollwagen said his company hopes to deliver a "limited number of developmental systems" in 1993. According to an industry source, Cray has teamed up for the project with MicroUnity Systems Engineering Inc., a Sunnyvale, Calif., firm; Cray has not publicly identified the company, however.

George Lindamood, a supercomputer analyst with the Gartner Group, noted that

EXPERT OPINION: Traditional mainframes and supercomputers are losing the battle

DAVID A. PATTERSON

Last year *IEEE Spectrum* asked if mainframes could simply disappear from the computing scene, and concluded from the announcement of many new mainframes that the answer was: "Of course not."

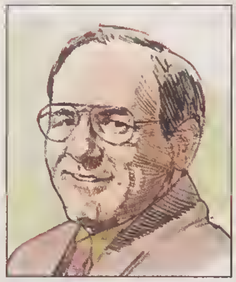
However, it's one thing to ask computer manufacturers, and quite another to ask their customers. This year the customers' answer to the same question is: "Perhaps."

Digital is a good example of the difficult business of selling mainframes. The DEC VAX 9000 competed hard with other projects within Digital, and won in part with sales projections of 1000 machines per quarter. After a series of delays, the sales goals were revised to 1000 over the life of the machine, and last year the VAX 9000 was finally announced as DEC's mainframe.

The sales during the first two quarters were less than a tenth of original projections, and recently quarterly sales dropped to just 25. At the end of that quarter, Digital said a new minicomputer in the VAX 6000 line, based on the CMOS technology, offers the same performance but at a much lower cost. The days of the VAX 9000 may be numbered.

The underlying problem is that the technology of workstations and personal computers, single-chip CMOS and bipolar CMOS (BiCMOS), is now winning out in performance as well as cost over the mainframe technology of many-chip emitter-coupled logic (ECL) modules. The much higher cost of mainframes is predicated on a very fast but very expensive technology. While the ECL chips and their necessary packaging have certainly been expensive, they are having trouble being faster. Some mainframe advocates had hoped that gallium arsenide would come to the rescue. As the accompanying story suggests, GaAs has yet to demonstrate that it can survive, given the rate of advancement of CMOS.

Computer historians may look back to 1992 as the beginning of the change in the definition of computer classes from the traditional model—desktop, minicomputer, mainframe, and supercomputer—to one defined by the number of CMOS or BiCMOS processors in the machine: 1-3, 5-10, 20-50, 100-1000, and so on. Such a transition has already begun, with virtually all minicomputers, mainframes, and supercomputers offering versions with up to a dozen processors. The next phase will likely be marked by an increasing number of old architectures implemented in CMOS, and then an increasing number of processors. Given software inertia and the conservatism of some customers, this transition will occur over the rest of this decade.



'Computer historians may look back to 1992 as the beginning of the change in the definition of computer classes to one defined by the number of CMOS or BiCMOS processors in the machine.'

MASSIVE SUPERCOMPUTING. Perhaps nowhere has this transition to parallel CMOS processors been so widely accepted as in the supercomputer market. Even though Cray Research Inc., Eagan, Minn., announced a major traditional (vector) supercomputer at the end of last year, the enthusiasm for this style of machine is waning. One of the Department of Energy's national labs, which have long been bastions of Crays, announced it would replace its YMP-8 with a dozen workstations. Several other labs have selected newly offered massively parallel processors. Even Cray Research announced it was constructing its own massively parallel computers.

In this historical context, the new Thinking Machines CM-5 may prove to be a landmark computer. The CM-5 bridges the two standard approaches to parallelism of the 1980s: single instruction, multiple data (SIMD) found in the CM-2 and MasPar machines, and multiple instruction, multiple data (MIMD) found in the Intel IPSC and Cray Y-MP.

The single-instruction nature of SIMD simplifies the programming of massively parallel processors, but there are times when a single instruction stream is inefficient: when one of several operations must be performed based on the data, for example. An area where MIMD has the edge is in availability of components: MIMD machines can be constructed from the same processors found in workstations.

The CM-5 merges these two styles by having two networks: one to route data, as found in all massively parallel machines, and another to handle the specific needs of SIMD (broadcasting information and global synchronization of processors). It also offers an optional vector accelerator for each processor. Hence the machine combines all three of the major trends in supercomputing: vector, SIMD, and MIMD.

The CM-5 can be built around 32 to 16 384 nodes, each with an off-the-shelf RISC processor. Prices begin at about US $1 million and increase to well over $100 million for the largest version, which offers a claimed 1 teraflops in peak performance.

Perhaps as important as the scaling of processor power, input/output (I/O) devices can also be easily integrated. Hence a CM-5 can be constructed with 1024 processors and 32 disks or 32 processors and 1024 disks, depending on the customer's needs.

David A. Patterson (F) is chairman of the Computer Science Division in the Department of Electrical Engineering and Computer Science at the University of California, Berkeley. He was project leader of the original RISC I project and has authored four books and numerous articles on topics in computing.

Thinking Machines, Intel Corp., Santa Clara, Calif., and Kendall Square Research, a Waltham, Mass., start-up company, are all planning to introduce 100-gigaflops-class massively parallel machines; Intel and Thinking Machines may manage to do so later this year. As with most other firms working with the technology, Cray Research's longer-term goal is to build a machine capable of sustaining 1 trillion floating-point operations per second (1 teraflops)—in Cray's case, by 1997, Rollwagen wrote in his memo.

Cray, in late October, was considering buying some of the assets of FPS Computing (formerly Floating Point Systems Inc.). The Beaverton, Ore., company, which finally filed for bankruptcy protection after several years of financial difficulties, pioneered both the minisupercomputer concept *and* the very long instruction word architecture—two of the more interesting technical advances in computing in the 1980s.

ADVANCED MACHINES TO DEBUT. Although most of the attention in supercomputing last year was on massive parallelism, this year is likely to see the resurgence of the conventional supercomputer (the kind based on fewer but more powerful processors). Last November, Cray Research took the wraps off its long-awaited C90, and two other high-end conventional supercomputers are expected later this year from start-up companies spun off from Cray by former employees.

A preliminary performance report on the C90 processor by Jack J. Dongarra, an expert in supercomputer benchmarking who works at the University of Tennessee in Knoxville and Oak Ridge National Laboratory, Oak Ridge, Tenn., lists for a single C90 processor a 1-gigaflops peak rate, 915 megaflops on the 1000-by-1000 Linpack (a common benchmark), and 403 megaflops on the 100-by-100 Linpack.

Cray Computer Corp. in Colorado Springs, founded by none other than Seymour Cray, is expected to deliver its first Cray-3 to Lawrence Livermore National Laboratory in Livermore, Calif.; like the C90 it is a 16-processor, 16-gigaflops (peak) machine.

At presstime, few details were available on the status of the third machine in this group, from Supercomputer Systems Inc. in Eau Claire, Wis. Partly owned by IBM, Supercomputer Systems is headed by Steve Chen, a former Cray Research designer.

Last year also saw exceptional activity in the mid- and entry-level supercomputer classes. Cray Research, for example, introduced the Y-MP EL, an entry-level machine based on one to four CMOS processing units with a 30-ns clock. Peak performance per processor is 133 megaflops, the company said.

Having emerged as the dominant maker of minisupercomputers in 1989 and taken on Cray Research in 1990, Convex Computer Corp., Richardson, Texas, last year upped the ante: it introduced the world's first supercomputer family with processors based entirely on GaAs integrated circuits. Priced from $2 million to $8 million, the C3800 series can be configured with one to eight processors comprising GaAs chips with up to 45 000 gates apiece. Peak processing rates per processor are about 120 megaflops in double-precision.

Although Seymour Cray has been working with GaAs for years and many had expected the Cray-3 to be the world's first supercomputer based on the technology, Lindamood noted that Convex's achievement should not be interpreted as a drubbing of the industry legend. The semiconductor fabrication method used to produce Convex's C3800 processor chips is Vitesse Semiconductor Corp.'s H-GaAs III process, an adaptation by the Camarillo, Calif., company of the MOS process in silicon. And like the complementary MOS process, it trades off speed for low-power consumption. The GaAs process being pursued for the Cray-3, on the other hand, is more akin to the emitter-coupled-logic technology in silicon: more technologically challenging, it aims at speed regardless of power consumption.

At its May introduction of the C3800 family, Convex also unveiled the C3400 series, now the middle of its range. According to Convex, each C3400 processor (there can be up to eight) is based on a combination of GaAs and bipolar-CMOS chips, and performs at 47 megaflops in 64-bit precision on the 1000-by-1000 Linpack.

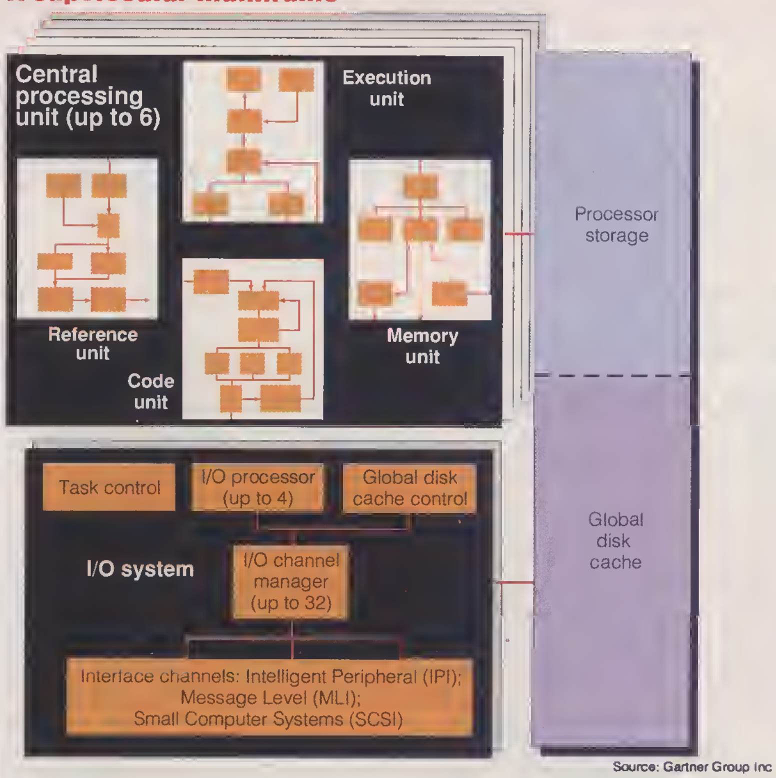
IBM's longstanding efforts to establish itself in supercomputing are not limited to its links to Supercomputer Systems and Thinking Machines. Last year, the company upgraded its vector processors by doubling the number of pipelines and adding nine instructions. All told, the improvements have boosted vector performance by a factor of 2.8 to 3.75, according to IBM.

Thus a top-end IBM ES/9000 model 900 mainframe fully configured with six vector units achieves 1.457 gigaflops on the 1000-by-1000 Linpack benchmark, according to Dongarra. A full eight-processor Cray Y-MP/832, for comparison, achieved 2.144 gigaflops on the same benchmark. (Both machines claim a peak performance of 2.6 gigaflops; no figure was available for the IBM machine on the 100-by-100 Linpack.)

"There shouldn't be any question any more about whether IBM has a supercomputer or not," said Tom Jarosh, IBM's vice president for technical computing systems in Milford, Conn.

With IBM and Convex in the fold, and Supercomputer Systems and Cray Computer about to join, the number of U.S. makers of conventional supercomputers could reach five by year's end—a far cry from the market devoid of competition that some had feared just two years ago after Control Data Corp. discontinued its supercomputer subsidiary, ETA Systems Inc. ◆

A superscalar mainframe



The processor design of Unisys Corp.'s A19 is based on four subunits and an elaborate I/O module. The company claims single-processor performance of 51 million instructions per second and each A19 can have up to six processors.

Telecommunications

- **Optically amplified optical-fiber systems planned**
- **Personal communications services take off**
- **'Baby Bells' can offer information services**
- **Intelligent networks are the next challenge**

The year 1991 boasted developments in all aspects of telecommunications: technology, business, and regulation, with 1992 promising more of the juggernaut onslaught.

Worldwide, crucial technical and regulatory steps have been taken toward personal communications services (PCSs). In this form of wireless and mobile communications, a call goes to an individual rather than to a location. Last year the European Community agreed to adopt an international standard called GSM, which would free subscribers to roam across borders and receive calls regardless of the equipment or system used. This year the U.S. Federal Communications Commission will begin allocating spectrum for domestic PCS operators.

On the legal and regulatory front, in July, Federal District Judge Harold H. Greene agreed under protest to admit the seven Bell regional holding companies into information services. Greene was the judge who approved the Modification of Final Judgment (MFJ) exactly 10 years ago—in January 1982—and who has retained jurisdiction over the breakup ever since.

Concurrently, most of the countries of the world were spending last year preparing for the five-week-long 1992 World Administrative Radio Conference, to be held next month in Spain, in Torremolinos. This conference, known as WARC-92, will set up treaty-level agreements revising the existing radio frequency allocations to accommodate both satellite communication technologies and services that are fundamentally new and worldwide [see also Legal Aspects, p. 19]. The latter include digital audio radio, personal mobile communications, next-generation wide rf-band high-definition television, and deep-space relays. The revision will cover a great part of the spectrum from 10 MHz to 100 GHz, including communications satellites in low earth orbit.

Trudy E. Bell Senior Editor

WARC-92 may well be the last conference of its kind, because its sponsor, the International Telecommunication Union—a specialized body of the United Nations—is being completely reorganized.

Meanwhile, after Eastern Europe opened up and the Soviet republics claimed independence, international entrepreneurs rushed in proposing systems to upgrade their nations' often-antiquated telecommunications infrastructures.

This excitement has somewhat obscured the steady progress in Japan, the United States, and other industrialized nations in digitizing their own telecommunications systems and converting them into integrated-services digital networks (ISDN), capable of transmitting video and high-speed data as well as voice. This trend could be accelerated in the United States by a preliminary FCC ruling, which is allowing the telephone companies to transmit television programming for program providers without a cable television license.

ISDN ON THE MOVE. In the United States, at least, "the year 1991 was the most phenomenal year for ISDN, ever," declared Richard Aloia, assistant vice president for network access technology and the ISDN project manager at Bellcore Inc., Morristown, N.J. Making the year so good for Aloia was that all segments of the telecommunications industry—end users, local and interexchange carriers, makers of customer premises equipment, switch vendors, and applications software developers—agreed to a plan, called National ISDN 1, for implementing ISDN.

"It's one thing to have a standard," Aloia noted. "Now we finally have agreed on the steps—dealing with both technology and timing—for implementation in North America." Until now, ISDN has operated in vendor-proprietary versions that are inconsistent and incompatible in many ways, according to Aloia. "This has been one of the many contributors to ISDN's lack of success, so far," he said.

However, these systems have shown that the digital access transmission scheme for bringing subscribers ISDN's 144-kb/s throughput over embedded copper wire can operate reliably. Performance levels are as envisioned by the standard, and, what's more, costs and power consumption are coming down.

The seven regional Bell operating companies will begin implementing ISDN by the fourth quarter of 1992. Most should have their systems at least 50 percent installed by the end of 1994. Two regionals, Bell Atlantic in Philadelphia and Ameritech in Chicago, said they should be 90 percent installed by then.

Helping move the implementation along is the better communication (it began last year through an industry forum in Washington, D.C., in July) among equipment developers, end users, and the people who write the technical requirements. During the week of November 16–22 of this year, the inauguration of the National ISDN will be boosted in various parts of the country by open houses at which end users will show how they are applying the National ISDN 1 network to benefit their businesses.

Meanwhile, undersea lightwave cable systems have transformed the quality of transmission and the services offered in international communications. The first generation of systems primarily operate at 280 Mb/s at a wavelength of 1.3 μm (the wavelength of least chromatic dispersion). By 1990, they linked many locations in North America, the Western Pacific, and Europe. Now the second generation of systems—primarily operating at 560 Mb/s at a wavelength of 1.55 μm (the wavelength of least attenuation) will augment these routes as well as add the South Pacific, Southeast Asia, and other points to the digital network.

Now, according to Peter K. Runge and Jack M. Sipress, both involved in undersea systems work at AT&T Bell Laboratories, Murray Hill, N.J., the third generation of undersea lightwave technology is being planned: the transmission of standard light pulses that are amplified by erbium-doped optical-fiber amplifiers. This kind of amplifier is basically a section of optical fiber doped with the rare earth erbium and later optically pumped with a laser diode. Such an all-optical amplifier has two advantages: it eliminates the traditional electronics needed to detect the pulse, convert it into an elec-

HIGHLIGHTS

Success: Agreement was reached on the National ISDN 1 standard for implementing integrated-services digital networks.
Shortfall: "Telepoint" public mobile pay telephone service proved unsuccessful in Europe.
Notable: Wireless mobile personal communications services were poised to become reality.
Newsmaker: Bell regional holding companies were allowed to offer information services over the phone lines.

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tronic signal, reshape the pulse, and use it to activate a laser to emit another pulse; it also amplifies a range of wavelengths at once, allowing several signals at different frequencies to be multiplexed onto one fiber.

Last year the AT&T investigators conducted tests to demonstrate the feasibility of using optical amplifiers for long-distance transmission. In one test, light pulses at 10 Gb/s over 2000 km showed a bit error rate lower than 1 in 10^{13}—a rate that is considered error-free. The test section will become part of a 9000-km-long facility to be jointly constructed in Freehold, N.J., by AT&T and Kokusai Denshin Denwa (KDD) of Tokyo. By 1995, the two companies plan to put into service the world's first transpacific undersea system using optically amplified lightwave transmission.

ONE DOWN, TWO TO GO. Ever since the AT&T divestiture took effect on Jan. 1, 1984, the seven Bell regional holding companies have been lobbying the U.S. Congress to free themselves from the three chief restrictions of the MFJ. The MFJ forbids the Bell regionals from offering information services, from manufacturing equipment, and from offering interexchange long-distance services.

The Bell regionals claim that the MFJ's restrictions keep them from being fully competitive in the United States and abroad. Opponents claim, however, that those constraints protect consumers against the same kind of alleged abuses that caused the U.S. Government to bring suit against the Bell System in the first place.

EXPERT OPINION: Coming soon—adding, modifying services quickly

ISRAEL ZIBMAN

Computing technology has long been the basis for telephone switching and network management. Yet, the recent advances in personal, desktop computing, and networked databases have had little effect on the customers' perception of telephone services. Now, techniques to permit external computers to direct the steps of call processing will allow subscribers to personalize the services they use and create new applications for the telephone.

Efforts are ongoing to standardize these techniques and so bring the advantages of the "open systems architecture" movement in computing to communications as well. That movement may shift the opportunity and responsibility for new services from the switch vendors to the telephone service providers and their customers. The challenge facing the telecommunications industry is to provide a new network structure open to the rapid introduction of innovative services while maintaining reliability and security.

'The challenge facing the telecommunications industry is to provide a new network structure open to the rapid introduction of innovative services while maintaining reliability and security.'

At present, the software for enhanced telephone services (such as call waiting, speed calling, and call distribution) is built into the central office switch or the private branch exchange. Creation and testing of that software is both costly and time-consuming. Software supporting the new operations must also be modified. Thus, months or years may pass before a new service can be deployed—and once deployed, the opportunities for change are limited.

Two efforts to allow new services to be introduced quickly and modified easily are now under way in the telecommunications industry. Known respectively as the Switch Computer Application Interface (SCAI) and the Intelligent Network (IN), both offer the opening for rapid deployment of new services. Both are the subject of standards committees at the national and international levels. The two approaches differ in the interface between the computer and the switch, the ownership of the computer, the degree of call-processing control given to the computer, and the degree of access to other telephone network resources.

In a nutshell, computers communicating through the SCAI interface will be owned by the subscribers, usually businesses, that will have complete freedom to design SCAI applications. Its simplicity and the limitations of the interface protect the network against applications that might damage the integrity of the public network. Nonetheless, very sophisticated call delivery and transfer services are possible. The SCAI computer can be networked into other subscriber workstations and databases, allowing caller-specific records to be made available to the call recipient.

A U.S. standard for SCAI is being developed by an American National Standards Institute (ANSI) committee and is expected this year. The European Computer Manufacturers Association (ECMA) is also developing a standard. Northern Telecom Ltd., headquartered in Ottawa, Canada, has announced plans to provide that capability in a central office switch. It already appears in some form in many private branch exchanges (PBXs), and most leading computer companies provide software packages that exploit the interface.

While the SCAI interface is, in a legal sense, customer premises equipment, the intelligent network (IN) will be a complete infrastructure in the telecommunications network for creating, testing, deploying, and operating new services. All communications will be by means of standard interfaces. The computers will be accessible through the Signaling System 7 common channel signaling network implemented in Japan, the United States, and Western Europe. Data and logic will be distributed throughout the network, allowing common features to be shared by subscribers and subscriber groups using home, office, and personal communications equipment.

ANSI, ECMA, and the International Telegraph and Telephone Consultative Committee (CCITT) for the International Telecommunication Union are discussing IN standards. The first recommendation is expected by CCITT this year. Meanwhile, Bell Communications Research (Bellcore), Livingston, N.J., has put a good deal of effort into developing Technical Advisories detailing their approach, called the Advanced Intelligent Network (AIN). AT&T Co., GTE Corp., Stamford, Conn., and several of the Bell regional holding companies are sharing in the AIN effort.

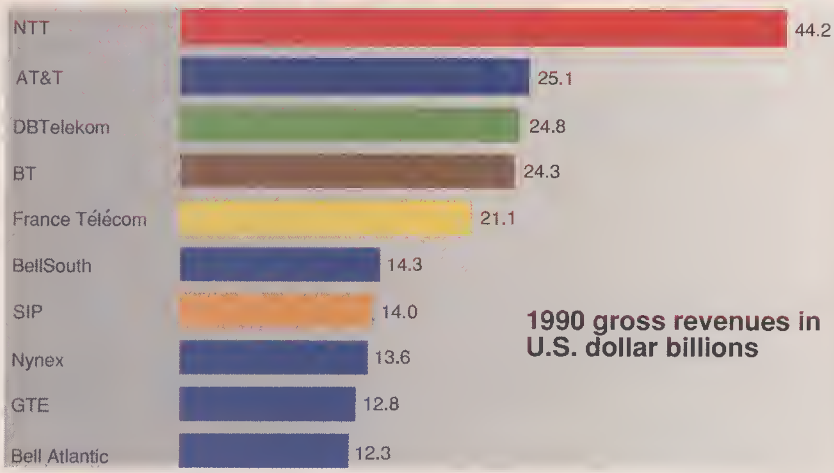
One challenge is learning how to create and test new services that will interact with existing services on the switch and on external computers. The other is reliability. Over the last two years, with several telephone outages in the United States, it has become all too evident how vulnerable the Signaling System 7 network is to software errors. Intelligent networking will place even greater demands on this system. Security methods must be developed to protect the integrity of the network and subscriber databases.

In addition, there are unresolved regulatory issues over how any rapidly developed new services will fit into the tariff system. There is also discussion about how and whether IN will satisfy FCC requirements for Open Network Architectures, which requires giving providers of differing types of enhanced services comparable access to certain network capabilities.

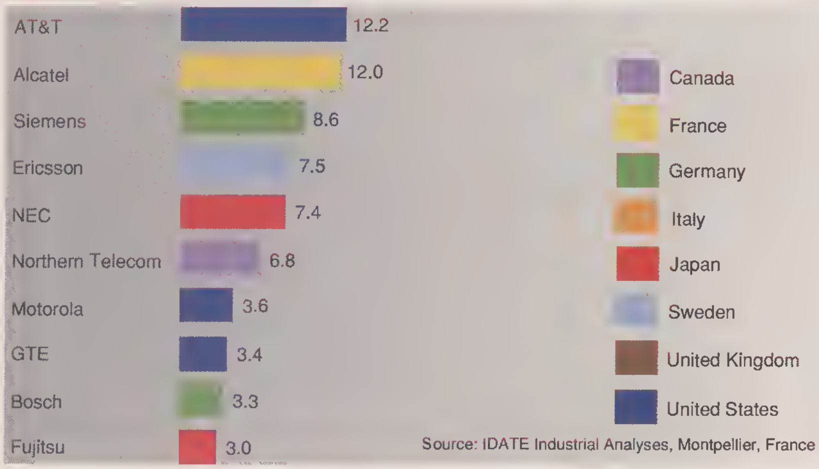
As the technical and policy problems are resolved, SCAI and IN will bring about shifts in how switch vendors, service providers, and subscribers provide and use telephone services. Nonetheless, the new infrastructures should accelerate the development of novel applications of, and expand to include, services for wireless, high-speed broadband, and multimedia services.

Israel Zibman (M) is a staff scientist in the Telecommunications Research Laboratory of GTE Laboratories Inc. in Waltham, Mass., where he is the technical leader in GTE's effort to develop a service logic execution environment—that is, adjunct computers that will work through the SCAI interface with the intelligent network.

The world's top 10 telecommunications equipment makers (73 percent of the market)



The world's top 10 telecommunications services companies (64 percent of the market)



BT = British Telecommunications; DB Telekom = Deutsche Bundespost Telekom; SIP = Italtel Sistemi-Impianti e Progettazioni

In 1990, the U.S. Court of Appeals ruled that Judge Greene had applied the wrong section of the MFJ when, in his triennial review of the MFJ's restrictions in 1987, he denied the Justice Department's motion that the regionals be allowed to enter the information services industry.

In a landmark ruling last July 25, Greene said that the Appeals Court decision left him with few options but to overturn his original prohibition on information services, and so permit the seven Bell regionals to offer such information services as home banking, audiotext, and electronic shopping. Greene said he was uncomfortable with the implications of "turn[ing] a key ingredient of the emerging information society over to corporations who not so long ago were involved in major violations of the antitrust laws."

Meanwhile, every year since the divestiture a number of bills aimed at removing the MFJ's manufacturing restrictions have been introduced into the House of Representatives and the Senate [see "Bell breakup plus five: mixed reviews," *IEEE Spectrum*, December 1988, pp. 26–31]. So far none of the bills has passed into law, although last year the Senate passed one proposed by Senator Ernest F. Hollings (D-S.C.), to remove the manufacturing restrictions as long as the Bell regionals used a certain percentage of U.S.-made components.

FUTURE TELEPHONY. Personal communications services (PCS) could far exceed today's cellular communications services in size because PCS will be basically radiotelephone networks, and these are more sophisticated and widespread than mobile or cellular systems. So said Benn Kobb, telecommunications consultant at New Signals Research, in Falls Church, Va. When mature, he said, a PCS might comprise a global wireless intelligent network that could identify users anywhere in the world and reach individuals regardless of their location—whether on board an airplane, in an elevator, or walking the dog on the street.

The key to PCS is low-cost, pocket-sized terminals operating at a power of less than 1 W, communicating through base stations that could be indoor and outdoor and smaller than a personal computer, in microcells only a few hundred meters across. Such microcells—only a hundredth of the area of the cells in current cellular systems—allow a few frequencies to be reused thousands of times in any urban area, so that hundreds of thousands of users on the move may talk simultaneously. Through an international group of connectivity standards now in development, the various PCS networks in various countries would be linked into one global system. Called Future Public Land Mobile Telecommunications System (FPLMTS), it will be discussed at the World Administrative Radio Conference next month.

Canada has already begun to assign frequencies. Last year the FCC published its PCS policy statement, and announced that perhaps as early as this year it plans to begin allocating frequencies in portions of the 1.8–2.2-GHz band to commercial companies. It will also keep on licensing experimental PCS operators; more than 100 licenses have been applied for so far. In the United States, companies interested in PCS are not only the traditional telephone and cellular outfits, but also the cable television companies—with some of the nation's biggest multiple-system operators investing in experimental licenses.

The only real setback is that a new type of mobile service in the United Kingdom called Telepoint—a public cordless payphone service—was an economic failure. All carriers closed their Telepoint operations, although at least one is considering relaunching the service in the future.

Meanwhile, the demand for standard mobile communications has gone on climbing throughout the world, even if its rate of growth has been somewhat slowed by the recession. In Japan, which was one of the first countries to offer mobile phone services in 1979, the number of subscribers has doubled each year, passing the 1 million mark in July. Nippon Telegraph & Telephone Corp. (NTT) projects that figure will rise to 8–12 million by the end of this decade. The current 1 million customers corresponds to 1 percent of telephone subscribers in Japan, as compared with 2 percent in the United Kingdom and the United States, 5 percent in Norway and Finland, and 6 percent in Sweden.

In some big cities of some countries, mobile analog systems are nearing saturation and the operating companies are starting to switch to digital systems. To encourage communications across national borders, last year the EC agreed on a time-division multiple-access digital standard called GSM (for Groupe Spéciale Mobile). With GSM-compatible systems, it is anticipated that travelers will carry a plastic "smart card" that will give them access to advanced cellular phones in more than 15 countries, and have every call billed to a single account without extra paperwork. The phones themselves, no matter their manufacturer, will work in any country agreeing to GSM. ◆

Data communications

- **Public frame relay service deployed**
- **Fiber standard proposed for voice plus data**
- **National research network gets faster backbone**
- **Mergers, alliances, joint ventures flourish**

During 1991, data communications continued its metamorphosis toward an expected blending with telecommunications. Boundaries between the two industries still hold, but the underlying structures have been shifting. Consider some recent events:

• NEC America Inc., Melville, N.Y., which makes communications products ranging from facsimile machines to integrated-services digital network (ISDN) central office switching systems, teamed up with Cisco Systems Inc., Menlo Park, Calif., which makes internetworking products, such as routers and bridges. They developed an interface that enables routers on local-area networks (LANs) to connect to switched multimegabit data service (SMDS) networks.

• The first carrier to deliver end-to-end frame relay performance (with its well-publicized boost to the interconnection of local-area networks) on a public network was not one of the leaders in the field but WilTel Inc., Tulsa, Okla.

• The U.S. House and Senate passed legislation establishing an ultragigabit-per-second National Research and Education Network (NREN). Preliminary steps taken toward deploying this information superhighway included gigabit-network testbeds and the cutover to a 45-Mb/s backbone for the National Science Foundation Network (NSFnet) used by the scientific research and university community nationwide.

• A new networking standard called Fiber Distributed Data Interchange II (FDDI-II) aims at helping to bring about multimedia transmission. To improve the original FDDI standard, an American National Standards Institute (ANSI) committee was expected to approve before year end the provision of a network management protocol that would comply with the guidelines of the International Organization for Standardization, Geneva.

The envisioned fiber-based gigabit-per-second public networks, the emerging interconnection technology for accessing these networks, and the user demand for linking high-speed LANs all add up to a year of kaleidoscopic change.

Sue J. Lowe Contributing Editor

TACTICAL ADVANTAGE. Industry giants shook hands across a variety of communications gaps in 1991. IBM Corp. and Digital Equipment Corp., Maynard, Mass., both formed alliances with Novell Inc., Provo, Utah, which has a large installed base of the LAN operating system NetWare. Some users are therefore wondering about the fate of IBM's LANServer, which competes with NetWare and is based on software made by Microsoft Corp., Redmond, Wash.

DEC, second only to IBM in the computer market, seems to have covered its interoperability bases by not only reaffirming its support of NetWare but also allying with Microsoft, the nation's No. 1 maker of software.

Many joint-development efforts were announced for connecting LANs to SMDS, which was tested in trial installations by regional Bell operating companies throughout 1991. The NEC and Cisco effort was only one of many SMDS-related alliances. Members of a SMDS interface consortium formed in 1991 include both makers of internetworking equipment—Advanced Computer Communications, Ungermann-Bass, and Wellfleet Communications—and vendors of wide-area networking (WAN) equipment—Digital Link and Verilink.

One of the more thought-provoking joint ventures of 1991 was between IBM and Apple Computer Inc., Cupertino, Calif. The prospect of a smooth integration path between PCs and Macintoshes is good news to many users in the data communications community [see "Software," pp. 30–32].

Asked to identify some underlying patterns in 1991's tangle of company alignments, Marty Palka, senior industry analyst for networking at Dataquest Inc., San Jose, Calif., pointed out that in a year of unstable economic forecasts, people looked for a tactical edge. Companies in the networking arena, he said, saw more ways to position themselves for the future.

For example, there is a trend now toward buying preconfigured LANs from mass merchandisers rather than going to a value-added reseller who markets the hardware and software components as a package. A company that makes network interface cards could foresee a need to, say, put the interface functionality on a chip, put that chip in a PC, and call the PC "network ready."

A case in point: Western Digital Corp., Irvine, Calif., sold off its network interface card business to Standard Microsystems Corp., Hauppauge, N.Y. That gave Standard a share in the older market that still uses network interface cards. It also freed Western to concentrate on its semiconductor side. "If you offer network-interface functionality on a chip that could reside on the motherboard instead of offering an interface card, you now sell to the CPU manufacturer—not through the card distributors. This sent a signal, said Palka, "to other vendors in the networking industry: here's a player that's positioning for the future in a different way."

LINKING LANs. Eliminating the bottleneck that occurs when high-speed LAN traffic must travel over a wide-area network (WAN), which typically transmits more slowly than a LAN, is an ongoing project for network designers and product manufacturers. The effort gained momentum when a public frame relay service was deployed in 1991.

Like other packet-switching technologies, frame relay belongs both in data communications and in telecommunications. A standard was developed by ANSI that specifies the frame relay interface between a LAN or data terminal and a public or private WAN.

In 1991, the Frame Relay Forum, Mountain View, Calif., got together to help ensure that different vendors' implementations of the technology would work together. Now with 70 members, the forum has been joined by most of the bigger players in LAN and WAN internetworking. Industry observers believe the group's cooperation was largely responsible for frame relay's quick move from emerging technology in 1990 to available technology in 1991.

In the context of the carrier's network, frame relay is a type of packet switching that uses variable-length units of data called

HIGHLIGHTS

Success: Public frame relay service was deployed, offering speedier interconnection among local-area networks.

Shortfall: Network management succumbed to human error on Sept. 17, for which AT&T Co. was rebuked by the Federal Communications Commission.

Notable: Nodes on the nation's science and research network (NSFnet) are now linked by a 45-Mb/s backbone network.

Newsmaker: A flood of mergers and joint ventures throughout the industry indicate new approaches to competition.

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frames. In the context of the LAN, frame relay is an interface at the periphery of the carrier's network. Vendors of internetworking equipment, such as bridges, routers, and data service unit/channel service units (DSU/CSUs), have made their products compatible with the frame relay interface standard.

The first carrier to deliver "public end-to-end frame relay performance on the backbone as well as at the access points was WilTel," pointed out Steve Sazegari, principal analyst at Dataquest. He stresses the qualifier "frame relay performance" because the backbone multiplexers employ cell relay but from an "overall network point of view the service provides frame relay performance."

BT Tymnet, US Sprint, CompuServe, and Telecom Finland also announced frame relay offerings in 1991, and commitments for 1992 implementations came from AT&T, GE Information Services, Cable & Wireless, MCI, and Timeplex.

The appealing feature of public frame relay networks is that for not too high an investment users can link their LANs nationwide at high speeds. WilTel's service supports speeds ranging from 64 kb/s to 1.024 Mb/s. This is much faster than X.25 packet switching, which has been used since the 1970s and usually transmits no faster than 64 kb/s.

Although regional Bell operating companies also announced plans to conduct frame relay tests, they seem equally if not more committed to an even faster packet-switching technology: switched multimegabit data service or SMDS.

During 1991 most regional Bells conducted trials of this service. As a public packet-switched service, it offers 45-Mb/s transmission over Metropolitan Area Networks (MANs) and is therefore ideal for linking LANs to WANs; it is expected to offer 155 Mb/s in the near future.

SMDS access is defined in the IEEE 802.6 MAN standard, which is the basis for work being done in Europe on MANs by the European Telecommunications Standards Institute (ETSI) in Sophia Antipolis, near Nice in France. ETSI's equivalent of SMDS will be called connectionless broadband data service (CBDS). It will link LANs not only to MANs, but also to broadband integrated-services digital networks (B-ISDNs), which gained worldwide attention in 1991.

In 1991, manufacturers of customer-premises equipment began adding interfaces to SMDS network services. Cisco Systems, for example, began shipping routers that had SMDS compatibility at speeds up to 52 Mb/s. It also boosted its frame relay interface to accommodate that data rate and announced that its ISDN interface will be available within two years [see figure].

Demonstrations of B-ISDN prototypes were prominent at Telecom 91, a quadrennial exhibition and forum held in Geneva, Switzerland. B-ISDN will also play a major role in gigabit-per-second data highways like those now being studied in the United States.

EXPERT OPINION: The barrier to high performance is no longer bandwidth

VICTOR B. LAWRENCE

Gigabit networks, renewed interest in copper, fast-packet technology, and wireless networks were the highlights of 1991. Gigabit-per-second data networks with extremely low error rates at last became feasible due to advances in lightwave and very large-scale integrated (VLSI) circuit technology. Multimedia applications, with their hunger for bandwidth, are likely beneficiaries.

The data networks of the 1980s had smaller bandwidth-delay products. Thus, they used fairly straightforward algorithms for flow control, along with complex communication protocols, to reduce transmission costs and minimize the bandwidth required for recovery from errors. In contrast, today's gigabit—and tomorrow's terabit—networks are being designed for high bandwidth, low delay, and a low error rate.

'[One] barrier to high performance is. . . the speed at which the communication protocols must be processed. . .'

The change means that the barrier to high performance is no longer bandwidth availability or the transmission medium's efficiency; rather, the obstacles are the speed at which the communication protocols must be processed and the efficiency of the algorithms used to minimize packet loss or buffer overflow and the resulting retransmissions. In some designs, it may even be worth sacrificing bandwidth to protocol processing.

However, access to networks—whether from the desktop at 10 Mb/s to local-area networks (LANs) or from the customer location at 1.5 Mb/s to wide-area networks (WANs)—remains costly. So with the emergence of high-speed digital services, ways of reusing the large installed copper base are being explored, even though optical fiber is the medium of choice.

One technology being developed to provide 1.5-Mb/s access over twisted copper wire is the high-rate digital subscriber loop (HDSL), in which bandwidth-efficient modulation, equalization, and echo cancellation schemes combine with advanced digital signal processing and VLSI circuitry. A prime virtue of HDSL is its efficiency at transmitting data over the copper loop at rates approaching Shannon's theoretical limits, all without special engineering, repeaters, or conditioning of the wire pairs and despite the presence of bridge taps, gauge discontinuities, cross talk, and impulse noise.

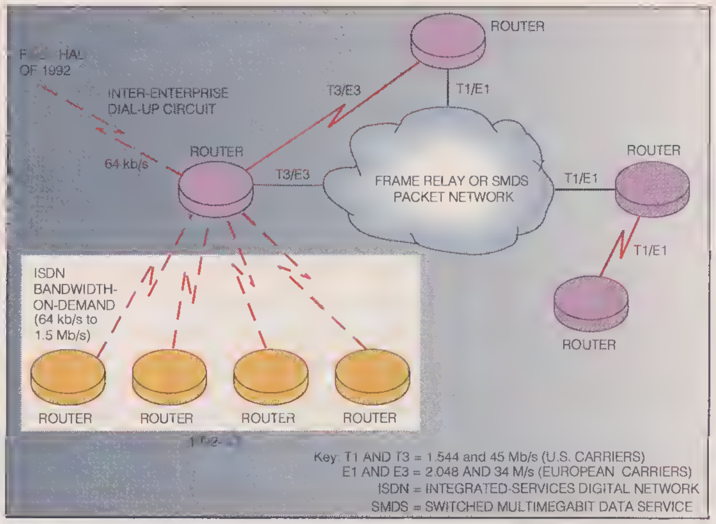
An HDSL variant is the asymmetrical digital subscriber loop (ADSL) for residential video-on-demand, entertainment, and educational services. ADSL uses one twisted pair to send 1.544 Mb/s in one direction above a bidirectional telephone line or basic-rate integrated-services digital-network (ISDN) channels; the loops may be up to 5.5 km long. Faster versions of ADSL are being developed at 45 Mb/s to the IEEE 802.9 integrated voice/data desktop standard. A still higher speed of 125 Mb/s over unshielded twisted pair is being developed as local access to backbone optical-fiber LANs in the ANSI/X3T9 fiber distributed data interface standard.

Fast-packet technology meanwhile made commercial headway, spearheaded by the introduction of several frame relay services. This technology is maturing for WANs with access rates of up to tens of megabits per second; it is an alternative to X.25 services. As for cell relay services, their advanced development continues. They are capable of combining variable- and constant-bandwidth traffic at aggregate speeds of gigabits per second.

But before cell relay services can go commercial with their short packet format, a new generation of circuits has to be developed for cost-effective switching and interfacing of the high-speed streams. Two service definitions for cell relay are likely to compete—switched multimegabit data service (SMDS), supported by the local exchange carriers and by much of the data-processing industry, and CCITT standards for asynchronous transfer mode (ATM) in broadband ISDN. The industry's transition to frame or cell relay service, however, is as likely to be driven by the business decisions of the service providers and their customers as by any technical superiority of one or the other system.

Wireless data networks, finally, also came in for their share of attention. These achieve speeds up to 20 Mb/s using either radio or infrared light for mobile networks and for indoor or campus-wide LANs. Such networks will reshape our lifestyles.

Victor B. Lawrence joined AT&T Bell Laboratories in 1974 and after assignments in signal processing and data communications became head of the data communication research department in Middletown, N.J., in 1988. He holds eight patents, has published over 40 technical papers, and has taught at several universities.



Internetworks in 1991 saw significant advances in both speed and connectivity. For example, Cisco Systems Inc., Menlo Park, Calif., added another wide-area network interface to its AGS+ router. As a result, the AGS+ can now route multiple protocols at rates up to 52 Mb/s in either dedicated point-to-point links requiring constant available bandwidth, or in packet-switched networks (frame relay or switched multimegabit data service), where data traffic has a greater tendency to occur in bursts.

Data networks in the research and education community picked up speed and membership in 1991. Internet, a data communications infrastructure that spans many countries, passed the milestone of half a million connected computers, including more than 100 000 non-U.S. computers, according to Mike Roberts, vice president for networking at Educom, a Washington, D.C., association of 600 colleges and universities. These computers represent multitudes of users, since some mainframes on the Internet may have as many as 4000 electronic-mail addressees.

In the United States a key component of Internet is NSFnet. Users of NSFnet, which links more than 2300 university, industry, and government research networks, gained access in 1991 to a backbone network that transmits data at 45 Mb/s (known as T3 speed). This high rate—compared to the network's previous T1 capacity of 1.5 Mb/s—results from the cooperative efforts of Advanced Network & Services Inc. (ANS), Elmsford, N.Y., which provides network services, and the Merit Computer Network, Ann Arbor, a consortium of Michigan universities, IBM, and MCI.

The ANS backbone network links up with NSFnet at many nodes. Upgrading the backbone to T3 speeds was completed in 1991 and makes it "the first public network to provide unchannelized 45 Mb/s," said Jordan Becker, ANS vice president. Most of the T3 lines in use across the country carry telephone traffic, so they are not used in unchannelized mode. Some data networks achieve T3 but, unlike ANS, by multiplexing T1 lines.

ANS also announced in 1991 that it has formed a commercial subsidiary called ANS CO+RE Systems Inc. This division enables companies in the private sector to send commercial data over certain portions of Internet. Federal rules bar the transmission of commercial traffic on most Internet portions.

Gigabit testbeds progressed around the United States during 1991. They are coordinated by the Corporation for National Research Initiatives (CNRI), Reston, Va., under a cooperative agreement with the U.S. government ["Gigabit networks," *IEEE Spectrum*, August 1991, p. 40]. The testbed technologies, according to Dick Binder, principal engineer at CNRI, include "Sonet, ATM, HiPPI [Synchronous Optical Network, Asynchronous Transfer Mode, and High Performance Parallel Interface] variable-length–packet switching, distributed shared memory, new network- and higher-layer protocols, host-interfacing and support software, remote visualization, and distributed computation applications."

Possibly simultaneous efforts to develop an information superhighway could conflict with each other. In 1991 the Internet Society was formed to provide a new framework for international collaboration among the thousands of organizations involved in the Internet's growth and use. The society, said Binder, will operate as a nonprofit organization for academic, educational, charitable, and scientific purposes.

FIBER NETWORK. Compared with the technological feats envisioned for NREN and the gigabit networks, the 100-Mb/s capability of Fiber Distributed Data Interface (FDDI) may seem pedestrian. But it is not the speed that causes some users to hesitate before implementing FDDI; it's mainly the cost.

Although a few optical-fiber networks that conform to the evolving FDDI standard are installed and operational, the standard did not become as popular during 1991 as many had expected. Two unresolved issues hampered wide-scale acceptance: which network management protocols to use, and which lower-cost twisted-pair wire to use instead of optical-fiber cable.

As solutions to these two issues are found, the standard changes. "FDDI is emerging in pieces," said Karen Parker, member of the ANSI X3T9.5 FDDI committee and FDDI strategic applications manager at National Semiconductor Corp., Santa Clara, Calif. In 1991 the committee proposed putting FDDI over twisted-pair wire. "Various companies actually built prototypes showing that the technology works: you can do 125-MHz signaling over unshielded twisted pair," noted Parker.

What type of twisted pair will be chosen by the committee from among the three proposals had not yet been decided at press time. The UDF (Unshielded Twisted Pair Development Forum) coalition favored using unshielded twisted pair; the consortium known as the Gang of Five supported using shielded twisted pair. The former includes AT&T Microelectronics, Berkeley Heights, N.J., and Apple Computer. The latter includes DEC and IBM. Another group, which included National Semiconductor, proposed the use of data-grade unshielded twisted pair.

This dispute notwithstanding, the chief FDDI players put on an impressive fiber showcase in October at the Interop 91 conference in San Jose, Calif. Forty-seven vendors brought their FDDI products and demonstrated that they all operate together. This is three times as many vendor combinations of FDDI products as were demonstrated at Interop in 1990.

Perhaps an even more dramatic development in the fiber arena during 1991 was the proposal of a new FDDI standard: FDDI-II. It passed Phase 1 (the letter ballot) of the ANSI standards procedure.

FDDI-II addresses the integration of multimedia transmissions. Sending data, voice, and video efficiently over FDDI has required too much bandwidth. The new protocol allows for hybrid ring control, including packet switching for text-based data and circuit switching for both voice and video transmission.

As FDDI-II progresses, FDDI-I will go on being fine-tuned. Like most standards, said Parker, FDDI-I keeps improving. She predicted that the FDDI committee's year-end meeting would resolve network management issues enough to bring FDDI into line with international standards.

Specifically, Parker expects that FDDI-I will adhere to the "guideline definitions for managed objects," as proposed by the International Organization for Standardization.

Another variation in network management, however, will haunt both the data communications and the telecommunications industries for the near future: it was the poor judgment exercised by human managers at AT&T. This, according to the Federal Communications Commission, contributed largely to the outage of AT&T's public network service throughout much of the New York metropolitan area on Sept. 17.

During an electrical power cutover between AT&T and Consolidated Edison Co. of New York Inc., personnel who monitor power levels for portions of the AT&T network were attending an off-site company meeting and so unable to witness an unlikely sequence of system failures. ◆

Solid state

- **RISC microprocessors for PCs?**
- **User-programmable ICs take off**
- **The era of the 3-V chip arrives**
- **Wafer fab price tag: $500 million and rising**

Reduced-instruction-set computer (RISC) architecture entrenched itself ever more deeply in 1991, as key microprocessor and computer manufacturers committed resources to the technology. Motorola Inc., Austin, Texas, for example, announced an agreement with IBM Corp. to manufacture microprocessors based on IBM's RS/6000 architecture. That agreement portends potentially revolutionary changes for desktop computers, which are now based almost exclusively on complex-instruction-set computer (CISC) architecture.

One of the key RISC products introduced was the fast and powerful R4000 microprocessor from MIPS Computer Systems Inc., Sunnyvale, Calif. The R4000 operates at 50 MHz and employs a 64-bit-wide architecture—the first microprocessor to do so. Included in the 1.2-million transistor chip are a floating-point processing unit, data cache, instruction cache, cache control, memory management unit, and a superpipelined central processing unit. MIPS offers the chip through six licensee manufacturers.

RISC chips are still used primarily in workstations, which are only a fraction of the microprocessor market. According to Dataquest Inc., San Jose, Calif., 387 000 RISC chips were sold in 1990 by all manufacturers, whereas Santa Clara, Calif.-based Intel Corp.'s 386 and 486 CISC chips alone totaled 7.5 million in unit sales.

RISC IN PCs. But the IBM-Motorola agreement may expand RISC applications in the massive PC market. Moreover, minicomputer and mainframe manufacturers like Tandem Computers Inc., Cupertino, Calif., and Digital Equipment Corp., Boxboro, Mass., announced plans to use RISC microprocessors.

Meanwhile, Intel, the dominant CISC manufacturer, has not sat idly by while RISC suppliers have boosted performance. Intel introduced low-cost (US $58) 16-MHz versions of its popular $202 33-MHz 386 chips and a 50-MHz 486 microprocessor. For 1992, Intel plans a four-million-transistor successor that will incorporate many features usually associated with RISC: superscalar architecture with multiple parallel execution of instructions, out-of-order execution for maximum efficiency, and superpipelining for greater parallelism and faster clocking.

George F. Watson Senior Editor

NO 386 MONOPOLY. Intel lost its monopoly position, however, when Advanced Micro Devices Inc. (AMD), Sunnyvale, Calif., began shipping in April clones of the 386 to customers and they responded enthusiastically. It was expected that AMD's share of the 386 market by the fourth quarter of 1991 would have reached 20 percent. Another new contender is Chips & Technologies Inc., San Jose, Calif., which introduced its own 386 clones in October.

AMD employs Intel microcode in its 386 chips, and claims it has a right to do so under a 1976 licensing agreement—a right that Intel hotly contests. Chips & Technologies, on the other hand, said it has scrupulously avoided infringing on Intel copyrights.

IBM, which makes 386 chips under license for its own use, established with Intel the Noyce Development Center in Boca Raton, Fla. There the two companies will work together to design more powerful microprocessors based on Intel's X86 architecture. They plan to add more and more computer functions per chip over the 10-year life of their technology agreement.

Intel also continues to upgrade its 860 family of RISC microprocessors. So far the new i860XP, with 2.55 million transistors and 32K bytes of on-chip cache memory, is the most highly integrated chip commercially available. It boasts a processing speed of 100 million floating-point operations per second (Mflops)—twice its previous rating and a new record. The chip is primarily used in high-end parallel-processing computers.

With the introduction of new transputers—microprocessors that have on-chip circuitry for direct and constant communication with similar microprocessors—the cause of parallel processing got a lift. SGS-Thomson Microelectronics Inc., Phoenix, Ariz., introduced the T9000 transputer, containing a 32-bit integer processor, a 64-bit floating-point unit, a 16K-byte cache memory, and a communications subsystem. Programming many T9000s to work together is just as easy as programming one, the manufacturer claims.

AUTO DEAL. Microprocessors' close cousins, embedded microcontrollers, reached new levels of integration, became easier to program, and attained even greater acceptance as embedded components. Ford Motor Co., Dearborn, Mich., and Motorola announced plans to co-design RISC microcontrollers for the auto manufacturer's engines and transmissions. When the design is complete in 1995, Motorola will start producing the devices for, eventually, more than 6 million cars and trucks a year.

During the year, too, RISC chips for embedded applications became more highly integrated. VLSI Technology Inc., San Jose, Calif., shrank linewidth from 2 micrometers to 1 μm, and in so doing was able to add 4K bytes of cache memory, a write buffer, and boundary-scan test circuitry to a 32-bit CPU on a chip (ARM 600) of essentially the same size. The chip was designed by Advanced RISC Machines Ltd., Cambridge, England. The U.S. company expects to produce a 0.8-μm version with still higher integration this year.

Another new line was introduced by Hitachi America Ltd., Brisbane, Calif., which unveiled its H8/500 series of microcontroller with optional on-chip electrically programmable read-only memory (EPROM). Unlike mask-programmed microcontrollers that take about three months to produce in the factory, the EPROM version is available for use as soon as a control program has been written for it.

With or without EPROM, the microcontrollers are designed for efficient programming in high-level languages such as C. Hitachi Ltd., Tokyo, calls its user-programmable feature ZTAT technology.

In the application-specific integrated cir-

HIGHLIGHTS

Success: The United States and Japan signed a three-year semiconductor trade agreement. The United States will no longer monitor Japanese prices and costs to detect "dumping"; Japan will step up efforts to increase U.S. producers' market share.

Shortfall: Worldwide sales of memory chips in 1991, at US $12.3 billion, were still 14 percent behind 1989 sales—a result of falling unit prices and sluggish PC sales.

Notable: The U.S. National Advisory Committee on Semiconductors proposed a crash program to manufacture 1G-bit static RAMs with 0.12-μm geometry by 2000.

Newsmaker: Senator Lloyd Bentsen (D-Texas) accused Japanese IC fabrication-equipment manufacturers of intentionally delaying deliveries to U.S. companies by as much as two years.

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cuits (ASICs) arena, their fast-rising career continued. The most explosive growth was in field-programmable gate arrays (FPGAs), whose market grew an estimated 94 percent in 1991, according to In-Stat Inc., Scottsdale, Ariz., and is expected to increase another 49 percent this year.

USER PROGRAMMING RISES. Engineers like FPGAs for the ease with which circuit patterns can be electrically impressed on chips—a much faster, and for low-volume orders, less expensive, process than using masks. Indeed, many engineers expect the dominant type chip for new designs [see figure, p. 44] will be user-programmable chips like ZTAT microcontrollers from Hitachi and FPGAs from Xilinx Corp. and Altera Corp., both in San Jose, Calif., from Actel Corp., Sunnyvale, Calif., and from others.

FPGAs have become more attractive as the number of gates on a chip has increased and computer-aided design tools have been developed specifically for them. Chips containing 8000 gates are now available, and the count is expected to rise to 40 000 in a year.

Mentor Graphics Corp., Wilsonville, Ore., customized a version of its Autologic logic synthesis and optimization software for FPGAs. The tool ensures that circuits are implemented in the least possible area; space savings of as much as 50 percent over general-purpose synthesis tools are reported.

Moreover, the tool is "technology-independent"; once the chip consumption grows large enough, Autologic can automatically optimize the design for mask-based ASICs such as gate arrays or standard cells. Other computer-aided design suppliers—like Cadence Design Systems, San Jose, Calif., and Synopsis Inc., Mountain View, Calif.—also support FPGA design synthesis.

Gate density is another area in which ASICs continue to grow. Mitsubishi Electric Corp., Tokyo, for example, introduced a 400 000-gate mask-programmable array. The CMOS chip—which comes in a 576-pin package—uses a proprietary gate-isolation method to shrink gate area.

Also beginning to appear are submicrometer-geometry bipolar-CMOS (BiCMOS) gate arrays. With only a slight increase in power consumption, they offer equipment designers denser chips with higher speeds than that of CMOS alone. Texas Instruments Inc., Dallas, announced a 150 000-gate BiCMOS array with 0.8-μm lines.

SMALLER SETS. Chip set suppliers packed greater functionality into fewer chips, driven by the demand for more compact

EXPERT OPINION: Solid-State research for defense systems

HARVEY C. NATHANSON

During 1991, defense R&D continued to reflect a demand for higher performance. In microwave IC research, for example, gallium arsenide depletion-mode field-effect transistors (FETs) working at about 10–25 GHz began being challenged by new structures promising operation at 150 GHz and above (indium-based heterojunction bipolar transistors and high-electron-mobility transistors).

Also now being explored are higher orders of radio-frequency integration in which antenna sections are fabricated on a single wafer and redundancy is used to provide adequate yield. As a result, commercial and consumer fallout can be expected—in automotive collision avoidance and personal communication networks, for example.

Other key research areas that are making headlines are low-cost silicon MOS devices for microwave and high-speed digital applications, high-temperature superconductivity for tuning and digital circuits, micromechanical circuits, silicon carbide, and using silicon for—of all things—long-wave infrared sensing and light emission.

'If silicon can be made to lase in response to an applied electric current, it could play as large a role in optoelectronics as it has in microelectronics.'

Meanwhile, silicon-on-insulator MOS radio-frequency transistors are being studied for affordable radar, electronic warfare, and communications at frequencies as high as 10 GHz. So far, self-aligned, 0.35-μm-channel MOS transistors have been integrated in amplifiers having 10-dB gain at 10 GHz. Ways have been found to preserve the substrate's high resistivity (greater than 1000 Ωcm) during annealing and full CMOS processing. The payoff will be a new generation of silicon chips for intermediate-frequency and baseband radar circuits at and below 10 GHz, where more costly gallium arsenide chips have been the only choice.

Micromechanics, once thought of in terms of miniature electrostatic motors and automotive pressure sensors, has found a new potential use: extremely accurate timing—10 000 times more accurate than crystal oscillators. Research has started on gaseous ICs in which a dime-sized cylindrical glass cell containing a vapor of a transition metal such as cesium is pumped by a semiconductor laser to produce a population inversion. Meanwhile, a microwave circuit "tickles" the gas, depopulating it when the microwave frequency is precisely matched to the resonant frequency of the gas atoms. This depopulation occurs at 9.1 GHz—accurate to 11 decimal places. Researchers plan to develop the micromechanical device into a low-cost atomic clock for service in stealth aircraft programs and "friendly" fire avoidance systems, for example.

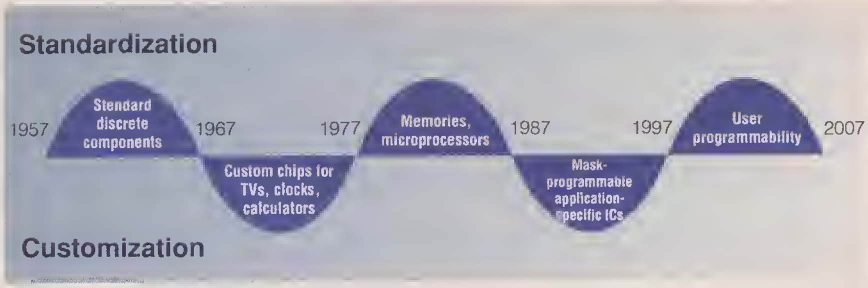
High-temperature superconductivity research, generously funded by the Defense Advanced Research Projects Agency (Darpa), produced a 10-GHz RF tuner that operates at 80 K. The search for a reliable high-temperature superconducting logic element continues. When found, it will yield massive computing nets whose extremely low power dissipation will be attractive even when the power for refrigeration down to 80 K is taken into account.

New work on growing 5-cm-diameter, almost defect-free wafers of silicon carbide promises transistors and variable-capacitance devices having 100 times the power-handling capacity per unit area of silicon or gallium arsenide. Difficult as silicon carbide is to process, the Department of Defense will be using the material in oscillators producing hundreds of watts at 10 GHz in the next few years.

Long-wave infrared sensing—important in missions where radar emissions must be avoided—is being studied in silicon, an unlikely candidate in view of its 1.1 electron-volt bandgap, so widely mismatched to the 0.1-eV bandgap appropriate for 10-μm waves. But new kinds of junctions make silicon sensitive to long-wave infrared; for example, both impurity-doped and heterobarrier (silicon-germanium) junctions have shown response to wavelengths ranging from 10 through 14 μm and beyond. An all-silicon charge-coupled device (CCD) with doped homojunctions promises high yield; potentially the price per pixel for such an infrared imager can rival that of commercial camcorders.

Finally, silicon has even become light-emitting: new porous-etch techniques create pillars of silicon, a few hundred nanometers in diameter, that emit red and orange light when illuminated by a laser. Once conversion efficiencies greater than a few percent have been achieved, silicon flat-panel displays may be possible. If silicon can be made to lase in response to an applied electric current, the material could play as large a role in optoelectronics as it has in microelectronics.

Harvey C. Nathanson (F) is chief scientist, Electronics, Information and Science Division, for Westinghouse Science and Technology Center in Pittsburgh. He has directed R&D on microwave materials, devices, and circuits, including gallium arsenide field-effect transistors, power ICs, and GaAs epitaxy. He holds over 30 patents related to semiconductor devices. He received B.S., M.S., and Ph.D. degrees from Carnegie Mellon University, Pittsburgh.



The semiconductor industry alternates between predominantly standardized and customized products every 10 years, according to Tsugio Makimoto, director and general manager of Hitachi Ltd.'s Semiconductor Design and Development Center. In "Makimoto's wave" (named by David Manners of Electronics Weekly*), the industry is now at the peak amplitude of a customization cycle, embodied in mask-programmed application-specific circuits. The next wave will begin in about five years, Makimoto predicts, when user-programmable chips such as field-programmable gate arrays and field-programmable microcontrollers gain wide acceptance.*

products with greater functionality. For example, National Semiconductor Corp., Santa Clara, Calif., introduced a data-path circuit for hard-disk drives that combines on a single chip a pulse detector, embedded servo detector, data synchronizer, write precompensation circuit, and frequency synthesizer. The DP8491 chip is part of a chip set for hard-disk drive control in laptop computers. The sets increase the capacity of physically smaller disk memories by modifying the data rate according to the read/write head's radial position on the disk, a process called zoned data recording.

Also geared to portable computer operations is a modem chip from Cirrus Logic Inc., Fremont, Calif. It combines in two chips the functions formerly done by five separate chips: microcontroller, host interface, digital signal processor, memory, and analog front end. The CL-MD1424 chip brings data, facsimile, and voice communications to laptops.

Another Cirrus product integrates almost all the functions needed to control a color liquid-crystal display (LCD) on a notebook computer. The CL-GD6410 requires only a couple of external memory chips and clock synthesizer; together the chip set fits on a motherboard only 5 cm square.

TRANSPARENT DSP. Digital signal processors (DSPs), as their prices come down, are being embedded in modems, speech recognition equipment, and other telecommunications products. "It's analogous to microprocessors," William Schweber, senior technical marketing engineer at Analog Devices Inc., Norwood, Mass., told *IEEE Spectrum*. "At first, they were expensive and you didn't find them in low-cost products. Now, of course, they're in everything from thermostats to microwave ovens. The same thing is happening with fixed-point DSPs; they are being embedded in certain applications and are transparent to the user."

Demand for high-end floating-point DSPs is soaring too. Design engineers are calling for floating-point devices, even though they are much more costly than fixed-point units, because they are easier to program and therefore reduce time to market.

The analogy to microprocessors continues with parallel processing for DSPs. Texas Instruments Inc. in Dallas introduced the first DSP chip, the TMS320C40, designed for parallel processing, with six ports for direct interprocessor communications, a six-channel coprocessor, a speed of 275 million operations per second (MOPS), and dual external buses.

The next generation of static random-access memories (SRAMs) made a preview appearance when four Japanese companies announced that they had made working prototypes of 64M-bit chips: Matsushita Electric Industrial, Mitsubishi Electric, Fujitsu, and Toshiba. The companies used various forms of photolithography to form 0.3–0.4-μm line widths. Production quantities are expected in two years.

VOLTAGE SHIFT. Most chip suppliers are preparing chips for a shift in power-supply voltage, from the usual 5 V to 3.3 V or less. High-density memories already operate at low voltages internally, but generally employ peripheral circuitry to interface with 5-V chips. "Originally it was thought that dynamic RAMs, because they drive the technology, would lead the industry to lower supply voltages," Betty Prince, manager, new products, MOS memories, at Texas Instruments in Houston, told *Spectrum*. "But as it turns out, the logic and processor people are bringing low-voltage products to market earlier."

The reason is that these suppliers are adopting ever-smaller geometries. "When they use line widths of half a micrometer or less, they are forced to lower voltages, both internally and externally," said Prince, who also chairs the Joint Electron Devices Engineering Council (JEDEC) committee charged with promulgating standards for low-voltage ICs.

Another motivation is the burgeoning of battery-powered portable computers and other equipment. Low-voltage ICs can run directly off one, two, or three nickel-cadmium batteries. Finally, higher speeds require finer lines and lower voltages; the 100-MHz microprocessors of the near future will run on 3.3-V power.

On the IC fabrication front, Sematech Inc., the Austin, Texas-based consortium of U.S. corporations and government agencies, moved closer to its goal of developing a totally integrated manufacturing system for chips with 0.35-μm line widths by 1993.

Sematech reported that it has developed electron cyclotron resonance (ECR) techniques to the point where requirements for multilevel metallization in 0.35-μm devices have been met. Sematech is concentrating on deep ultraviolet photolithography for the manufacturing system.

AT&T Microelectronics, Berkeley Heights, N.J., and NEC Corp., Tokyo, announced plans to jointly develop their own 0.35-μm process. They expect to manufacture chips with it by mid-1995.

BIG FAB INVESTMENTS. The cost of manufacturing systems continued its exponential rise. The Semiconductor Research Corp. (SRC), Research Triangle Park, N.C., which sponsors university research on behalf of U.S. and Canadian companies, reported that a high-volume wafer fabrication line now requires an investment of about $500 million. Both NEC and Toshiba, for example, spent that amount in 1991. These fabs have a life expectancy of only five years. By 1995, SRC predicted, a fully automated factory producing 25 000 wafers per month will cost $1 billion.

IBM began making prototype chips by X-ray lithography, using its huge synchrotron machine in East Fishkill, N.Y. IBM plans to make 256M-bit dynamic RAMs with 0.25-μm geometry and expects eventually to make 0.1-μm and even smaller geometries. Motorola and Munich's Siemens AG are participating. IBM's advanced technology facility, including the synchrotron, will have cost $750 million when it is fully operational in 1996.

SUPERCONDUCTOR PROGRESS. On the research front, several companies reported progress in building superconducting ICs. Conductus Inc., Sunnyvale, Calif., demonstrated a superconducting quantum interference device (Squid) magnetometer that employs a high-temperature superconductor (yttrium barium copper oxide). The chip combined for the first time a flux transformer and a sensor; formerly these components were on separate chips. The new device has seven thin-film layers: three of the superconductor, two of insulating material, a seed layer that creates grain boundaries for the chip's two Josephson junctions, and a silver layer for making electrical contact between layers and junctions. The chip operates in liquid nitrogen.

Another advance was demonstrated when Hypres Inc., Elmsford, N.Y., showed a superconducting 4-bit shift register that operates at 9.6 GHz and dissipates only 40 μW. The register contains 10 thin-film layers and 32 niobium Josephson junctions on either a silicon or a gallium arsenide substrate. It operates at 4.2 K (liquid helium temperature). ◆

Test and measurement

- ***Rise of RISC puts new demands on logic analyzers***
- ***Instruments rely less on PCs for intelligence***
- ***Testability issues grow in importance. . .again***
- ***Quantum standards loom***

The enthusiasm with which designers of digital systems are adopting reduced-instruction-set computer (RISC) architectures is profoundly affecting the test and measuring instruments needed to check out those systems. Whereas in conventional complex-instruction-set computer (CISC) processors many instructions require many clock cycles, the RISC goal is that every instruction be executed in a single clock cycle. But if that is great news for system designers, it certainly makes it tough to design an in-circuit emulator for such a device. Where is the emulator to find the time to make decisions about what to do next?

Add to that burden the increasing sophistication of the latest microprocessors with their on-board primary caches, built-in floating-point processors, and multiple pipelines, and one can see why many new processors may never get emulator support.

RISC LOGIC ANALYZERS. Absent an in-circuit emulator, the designer's second-choice tool for designing and debugging systems under development is the logic analyzer. Reflecting their appreciation of the increased role logic analyzers will be playing, instrument manufacturers have already began taking steps to make their products into superior real-time development tools. In 1991, Tektronix Inc., Beaverton, Ore., and Microtec Research Inc., Santa Clara, Calif., announced a strategic alliance with the pioneering aim of integrating a logic analyzer with software development tools. So far, the result of that alliance has been a package that combines Microtec's C, C++, and Pascal cross compilers and the company's XRAY in-circuit source-level debugger with Tektronix's DAS 9200 logic analyzer.

The effect of microprocessors on the development of test instruments has been interesting, to say the least. When microprocessors first came out, in the early '70s, test equipment manufacturers were among the first to appreciate their potential. The result was the initial wave of so-called "smart" instruments. Then, as engineers realized that no instrument would ever be built in the kinds of volumes associated with PCs, they reasoned that it would be wise to exploit the cheap processing power of the PC by going back to dumb instruments—albeit dumb instruments with a port for a PC.

Michael J. Riezenman Contributing Editor

MULTIPLE PROCESSORS. Most recently that trend is reversing itself again. Powerful processors and chips with huge amounts of memory are now attractive enough economically to put the brains back in the instrument. "Brains" plural is precisely the right word because the trend is, in fact, toward multiple microprocessors. The Keithley 2001 digital multimeter by Keithley Instruments Inc., Cleveland, Ohio, a recently announced example, contains five processors, which enable it to perform and display several measurement calculations simultaneously without affecting its front end sampling rate. The 7-1/2-digit meter displays frequency and crest factor as "extras" on its multiline readout while measuring ac voltage, for example.

In the microwave area, the model 1795 receiver from Scientific-Atlanta Inc., Atlanta, Ga., uses a multiple-processor architecture to update its phasor measurements at 200-μs intervals while providing real-time control over an IEEE-488 bus and a real-time data highway.

Oscilloscopes and spectrum analyzers are also making use of multiple processors, although not exclusively of standard commercial units. The Tektronix TDS 500 oscilloscope family, for instance, uses two Motorola processors, but its distinguishing component is a waveform-processing chip built by Tektronix itself. That device, essentially a 32-bit digital signal processor, performs complex waveform calculations in real time so that the user need not wait for an overburdened CPU to repaint the screen every single time he or she makes an adjustment to the circuit under test.

HIGHLIGHTS

Success: Logic analyzers are helping engineers develop and trouble-shoot high-speed RISC-based systems without in-circuit emulators.

Shortfall: Instrument designers are finding it hard to develop in-circuit emulators for the latest high-speed RISC chips.

Notable: Processing power is so cheap that some instruments have enough to rival personal computers.

Newsmaker: The National Institute of Standards and Technology built a laser system for a new optically pumped atomic-beam frequency standard, which is to have an uncertainty of 1 part in 10^{14}, an order of magnitude better than the present standard.

An important consequence of basing test and measurement instruments on microprocessors is that one can frequently improve a product just by rewriting or augmenting its embedded code, or firmware. Hewlett-Packard Co., Palo Alto, Calif., for example, announced several enhancements to its HP 8590 spectrum analyzer in 1991. Those enhancements, which took the form of plug-in ROM modules called personality cards, tailor it to specific applications.

One, the HP 85712C EMC auto-measurement card, adds custom diagnostic and automated precompliance-evaluation capabilities to the host analyzer. Its automated routines allow up to 20 signals to be evaluated with a single keystroke. The credit-card-sized module also contains an extensive library of setups for industry standard tests, such as those defined by the Federal Communications Commission and such international standards organizations as VDE and the International Special Committee on Radio Interference (CISPR), London. Other cards automate cable TV, digital radio, and scalar measurement routines.

BOUNDARY SCAN TESTABILITY. As it has been in recent years, testability is the biggest issue instrument designers face as they look toward the future. With more and more functionality being incorporated in fewer and fewer chips, the question is how to determine what is going on when you cannot access the action. Test equipment with lots of channels and lots of memory behind each channel can help, but something more is needed, and boundary scan seems to be shaping up as the answer.

Boundary scan supplies a standard means for providing electronic access to the insides of a chip via a test access port (TAP) consisting of four or, optionally, five pins- -a modest number considering that some ICs today have more than 200 leads. Two of the TAP pins provide for the serial input and output of data, while the remaining two or three control data movement.

Boundary scan should not be confused with built-in self-test (BIST) with which it can be combined to excellent effect. BIST features are normally used by IC manufacturers and are normally not available once a device has been packaged and assembled

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onto a board. Under boundary scan standard ANSI/IEEE 1149.1, however, there is an instruction called RUNBIST, which can be fed into an IC to initiate the BIST routine.

If BIST and boundary scan are provided in ICs and made available at the system level, the results can be quite spectacular. According to one industry study, the time required to develop system diagnostic software can be reduced by two-thirds. Some industry experts are even talking about embedded instruments—test equipment on a chip that can be included on printed-circuit boards to facilitate testing in the field.

In the standards area, work continues on intrinsic, or quantum, standards—standards based on the laws of physics instead of man-made artifacts. In 1990, new intrinsic standards for the volt and ohm were adopted by the International Committee on Weights and Measures. The voltage standard is based on the Josephson effect, while the one for resistance exploits the quantum Hall effect.

It now appears that the most precise standard in existence, the one for frequency and time, will probably have its uncertainty reduced by an order of magnitude before 1992 is over. Furthermore, it may well improve by two more orders of magnitude by 1995—to an astonishing 1 part in 10^{16}!

NEW STANDARDS. While optical pumping will be behind the short-term improvement, the technologies that promise to make the largest contributions in the long run are ion trapping, laser cooling, and a combination of the two. Both have the effect of isolating small groups of ions or atoms by suspending them in space, where their behavior is minimally affected by external influences. Ion traps take advantage of an ion's electrical charge to trap it in a static or oscillating electromagnetic field.

Since atoms have no net charge, they must be handled differently. The approach with them is to stop their motion by suspending them at the intersection of six laser beams (two for each Cartesian axis). If the laser wavelength is chosen correctly, the atomic motion in all directions can be brought to an almost complete stop, and the atoms held virtually motionless. In that state, their temperature is measured in micro Kelvins, and, when the laser beams are turned off, their behavior is dependent almost entirely on the intrinsic physical properties of the atoms alone.

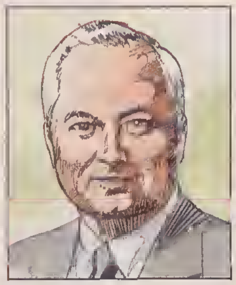
NBS-6, the present primary frequency standard, was built in 1975. It is a cesium-beam clock with an uncertainty of 8 parts in 10^{14}. NIST-7, which is currently under development, is expected to cut that uncertainty down to about 1 part in 10^{14} toward the end of 1992. It is also a cesium-beam device, but it employs optical pumping to minimize a variety of uncertainties—for example, microwave cavity phase shifts. ◆

EXPERT OPINION: Instruments bring users more information than ever

FREDERICK R. HUME

This is one of the most exciting eras in test and measurement instrumentation since the rise of the integrated circuit. The instruments available today are dramatically more versatile and powerful than those of just five years ago and provide users with more useful information than ever. This development is a direct result of the increasing computational power of the digital processors in the instruments and the increasing versatility of their displays.

While the design of the fundamental analog building blocks of instruments was mastered years ago, digital signal processing lets manufacturers put the blocks together in novel ways to perform new functions and provide more meaningful measurements in less time. For example, users have difficulty measuring ac voltage accurately if the signal is distorted. Yet few, if any, instruments provide a means for determining the signal's crest factor, a measure of distortion, so the amount of uncertainty in the measurement is unknown. Using digital processing, crest factor can now be measured and displayed. If it is below a given level, the accuracy of the measurement is assured.



'Today's instruments are dramatically more versatile and powerful than those of just five years ago.'

At one time, many tests required of users the expertise to integrate several instruments into a test system. More capable instruments mean that fewer of them are needed to perform a test. For example, one of the newest of today's multimeters measures the peak, average, and rms values of ac signals and noise, and in addition to the crest factor measurement, incorporates another innovative capability: current measurement without breaking the circuit.

To benefit to the full from this increase in digital processing, the display and human interface are being improved. Today's users are no longer content with a single display indicating one reading at a time. Multi-line displays and flexible menus, such as those available with virtual instruments and personal computers, improve the clarity of the information presented and reduce its access time. Meaningful information is displayed so the user does not have to extract it from raw parametric data. Other benefits, of course, are simplicity and ease of use. Tasks such as changing functions, figuring instrument settling times, and finding appropriate ranges are handled internally to improve throughput and minimize the chance of error.

An example of these trends is a recently introduced switch system and scanner, with a vacuum fluorescent display that indicates the status of all 80 channels simultaneously. With it, users can tell at a glance whether a channel is open or closed. Inserting additional switching cards into the scanner mainframe automatically configures the front panel display. Since users can check the card configuration and channel status quickly, system programming is simplified. Stored programs can be modified and debugged from the front panel. The display provides a rich selection of help files, setup and configuration prompts, and error messages.

When multiple instruments are needed, new digital architectures, such as the VXIbus, simplify their integration. Real-time software is needed to profit fully from time synchronization and should be available for production test system applications in the near future.

Fundamental improvements in instruments come at a price. Already their digital sophistication is enough to make built-in self-test desirable, and in some cases essential, to their manufacturability. As the versatility, accuracy, and functionality of an instrument increase, so does its internal complexity. Imagine the difficulty of testing each function of a complex instrument with a probe after it is completely assembled. Unless instrument design is done in concert with test engineering, the cost and time required to test a unit thoroughly becomes prohibitive.

Built-in test as used in the factory must identify whether the instrument works as intended, and if it does not, should highlight the source of the problem. While it may increase the development cost, it reduces ongoing costs in manufacturing and life cycle costs for the purchaser. Perhaps of most benefit to the user is the greater reliability and confidence built-in test provides.

Technological improvements, such as those noted above, will be embraced by nearly all instrument manufacturers in the future. These, along with progress in fundamental technology from recent scientific advancements, should markedly enhance the sensitivity, precision, and functionality of test and measurement instruments.

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Industrial electronics

- **Fuzzy logic expands**
- **Programmable logic controllers distributed I/O**
- **Keeping robot co-workers safe**
- **High-speed protocol for optical fiber**

Flexibility as well as more robust control are recurring themes in today's industrial electronics and factory automation. A new fear is for the safety of robot operators, as reflected in research projects in France and Japan. Fuzzy logic controls, computer-integrated manufacturing, machine vision, and neural networks, among other fields, have been moving ahead, each at its own pace.

Employed in such diverse systems as water pumps, tube welders, and radio private branch exchanges (PBXs), fuzzy logic controls, for example, are to come into their own this decade—from total world sales of US $1.5 billion in 1990 to possibly $13 billion by the year 2000. This market projection was confirmed for *IEEE Spectrum* by a spokeswoman for Togai InfraLogic Inc., Irvine, Calif., a five-year-old company specializing in the field.

Less impressive is a forecast for computers for factory automation. Automation Research Corp., a Medfield, Mass., firm that does market research in industrial automation, predicts a stagnation in sales of this type of computer in North America—about $2.7 billion for both 1989 and 1992.

Overall, however, the Massachusetts firm sees all factory automation systems in North America doing better, from about $6760 million in 1989 to $7360 million in 1992.

Among the big winners is software for computer-integrated manufacturing (CIM), whose annual dollar sales expanded by at least 15 percent in each of the last few years, according to David G. Johnson, manager of product marketing at GE Fanuc Automation North America Inc., Charlottesville, Va.

As of last April, GE Fanuc's Cimplicity factory-monitoring and control software has been adapted to run on personal computers using AT&T's Unix operating system. Thus there are versions for the IBM PC and compatibles, as well as for Hewlett-Packard and Digital Equipment computers.

Meanwhile the implementation of distributed control—one in which processing takes place in more than one processor—by programmable logic controllers (PLCs) is making headway. The move toward distributed control, particularly distributed input and output is the most significant trend in PLCs, according to David Shepard, product marketing manager for the 90-70 PLC made at the same GE Fanuc facility. New PLCs that work with distributed I/O emerged from such vendors as GE Fanuc and Mitsubishi Electronics America Inc., Cypress, Calif.

Gadi Kaplan Senior Technical Editor

GE Fanuc, for example, introduced two new PLCs in its 90-70 series. Named Model 781 and 782, the two have greater processing power (CPU scan rates up to three times as fast as earlier models, plus math coprocessor use) along with improved networking software.

Programming for PLCs has made big strides. Omron Electronics Inc., Schaumburg, Ill., introduced last May its C1000H and C2000H PLCs. Assisted by built-in fuzzy logic, their programming uses an operator's subjective knowledge rather than relying on precise modeling of the processes to be controlled, which is often hard to do well. Heavily committed to fuzzy logic, Omron estimates that nearly 20 percent of its products will go fuzzy by 1995. In another example, researchers with Hitachi Ltd.'s Energy Research Laboratory in Hitachi, Japan, developed and satisfactorily tested a method for verifying the software design for PLCs.

LOW-COST VISION SYSTEMS. With pressures building to improve product quality while keeping manufacturing costs down, many are likely to welcome last month's introduction of low-cost machine vision boards compatible with VMEbus-based computers. Cognex Corp., Needham, Mass., a leading vendor in the field, is offering its 4100 and 4200 single-board vision systems for original-equipment manufacturers to align and guide printed-circuit boards during component assembly and inspection. With software for simple alignment applications, the boards will sell for less than $10 000 each. Both boards employ the 68EC030 microprocessor and Cognex's custom VC-1 chip for high-speed implementation of the company's image analysis algorithms. The difference is in the speed—the 4100 runs at 16 MHz, the 4200 at 25 MHz.

Elsewhere engineers with Sony Magnetic Products Inc., Miyagi, Japan, have developed a vision system that can automatically detect errors in printed characters on videocassettes. The system employs a template-matching algorithm and uses normalized correlation of gray images.

It takes 1.2 seconds to process one cassette, according to the developers' paper given at the 1991 International Conference on Industrial Electronics Control and Instrumentation, held in Kobe, Japan, Oct. 28—Nov. 1.

FASTER X-RAY LAMINOGRAPHY. X-ray laminography, which probes the interior of solder joints to uncover voids and other defects, is gaining ground with recent introductions from two competing companies in San Diego, Calif.—Four Pi Systems and IRT Corp. Four Pi Systems introduced its 3DX Series 1500C system, which scans printed-circuit boards at up to three times the speed of the earlier model, Series 3000. The extra speed stems from an increase in the target area of the system's X-ray tube, and hence field of view. Increased automation speed and higher resolution (12 line pairs per millimeter at a field of view of 13 by 12 mm) is the value added to IRT Corp.'s CXI-03300, the company's newest model, which, the company claims, is the world's first "in-line" X-ray test system.

TAMING ROBOTS. Robots' potential for hurting their human operator was the topic of several papers presented at the Kobe conference. Researchers with Kobe University's Department of Instrumentation Engineering in Japan developed a human recognition system, so that a robot can of its own accord avoid trajectories that endanger human workers. The system employs four pairs of infrared and ultrasonic sensors arranged at 90 degree intervals around a cir-

HIGHLIGHTS

Success: Nearly 80 percent of all three-phase induction motors in the 0.6–450-kW range sold by Siemens Energy & Automation Inc., Atlanta, Ga., last year were of the newly redesigned, high-efficiency Medallion type.

Shortfall: The proliferation of nonstandard languages for motion control other than numerical control hampered the transfer of motion control technology to intelligent manufacturing systems.

Notable: Neural networks are being extensively studied for adaptive, self-tuning controllers, among other areas.

Newsmaker: Real-time scheduling of the workforce is achieved (in agreement with the local labor union) at Pirelli's cable manufacturing plant in Aberdare, South Wales, the United Kingdom, as part of the plant's computer-integrated manufacturing.

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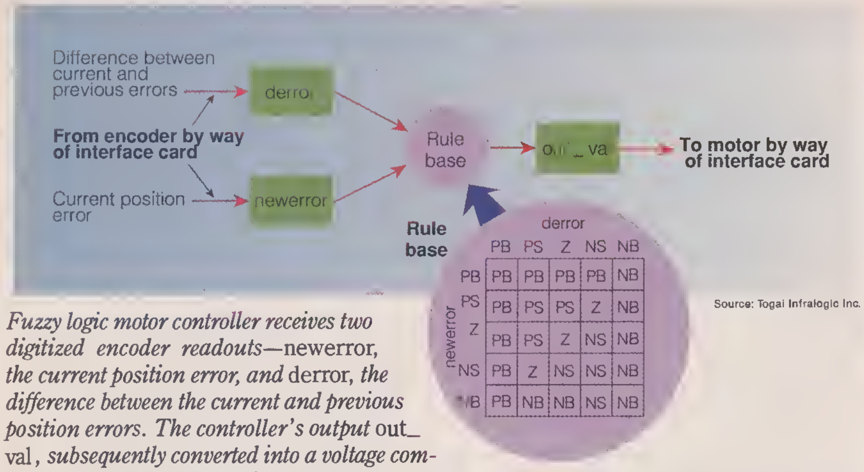

*Fuzzy logic motor controller receives two digitized encoder readouts—*newerror, *the current position error, and* derror, *the difference between the current and previous position errors. The controller's output* out_val, *subsequently converted into a voltage command to the motor, is derived from a rule base—an algorithm (shown in a table format) that defines the relationship of the input and output variables. Residing in memory, the rule base has groups of fuzzy membership functions, each representing one variable—positive big (PB), positive small (PS), zero (Z), negative small (NS), and negative big (NB)—instead of 0s and 1s. For example, one command is 'if* derror *is Z and* newerror *is PB then* out_val *is PB.'*

cular plate. Scanned regularly by a rotating table, the infrared sensors pick up the direction in which a person is moving near the robot and the ultrasonic ones indicate how far off he or she is. The collision avoidance algorithm takes into account the distance between the robot and human operator and their relative velocity, as well as the person's position and the robot's velocity.

Researchers with the Ecole Nationale Supérieure des Techniques Industrielles et des Mines de Douai, in Douai, and with the Université de Technologie de Compiègne, France, developed a technique using the difference between a reference image of the robot and one in which an object is intruding into the robot's danger zone.

DSP CONTROLS. For both robots and motors, more robust motion and speed control are in growing demand. For example, in several types of press machines and compressors, motors are increasingly relied upon to ensure an acceptable quality of product, by maintaining an all but constant speed, in spite of fluctuating load torque. A group of researchers at Nagoya University in Japan implemented a robust control of this nature of an induction motor by software, using a digital signal processor (DSP). The researchers reported less than 1.5 percent speed fluctutation in response to a step change amounting to 65 percent of the rated value of an opposing torque.

In another application, a group of researchers at the Korea Advanced Institute of Science and Technology in Seoul, controlled a prototype, 7.5-kVA three-level pulse-width modulation (PWM) inverter with a Motorola digital-signal processor.

Finally, if current research efforts bear fruit, the following may become available within the next two years:

- Neural network software that takes bitmap images of electron-beam-generated circuit patterns at line widths as low as 0.1 μ and compensates for scattering effects of the electron beams. Prototypes are in use at Hitachi and AT&T Bell Laboratories.
- The Protocol Engine, a chip set for the Xpress Transfer Protocol (XTP), a high-data-rate protocol particularly suitable for optical fibers, under development by an international group of researchers headed by Greg Chesson, chief scientist at Silicon Graphics Inc., Mountain View, Calif.
- Two highly automated repair systems for printed-circuit assemblies, in development at Westinghouse Electric Corp.'s Science and Technology Center, in Pittsburgh, under contract with the U.S. Air Force and Army.
- The first international standards on intelligent manufacturing systems, in development by groups under the Geneva-based International Organization for Standardization and the International Electrotechnical Commission. ◆

EXPERT OPINION: A crucial target is CIM open-system architecture

JAVIER UCEDA

In factory automation, information and communications play some of the most important roles. Lately some marked improvements have been achieved in interconnection of systems on the factory floor. Also, some steps have been improved in the way to establish a framework for a computer-integrated manufacturing (CIM) open-system architecture. Because the complexity of networks in manufacturing and engineering is increasing, this framework is a crucial target. For example, the Communication Network of Manufacturing Applications, a joint project of European companies is extending the Manufacturing Automation Protocol, particularly at layers 6 and 7 of the International Organization for Standardization's Open System Interconnection model. Results are already being used in production applications by such companies as BMW, British Aerospace, and Aeritalia.

'We are far from the intensive application of autonomous robots integrating mobility, manipulation, and perception in a non-artificial environment...'

Some improvements have been achieved in robotics—the robots are becoming more flexible, intelligent, and precise, and they are also demonstrating enhanced real-time control, decision-making, and self-teaching capabilities. However, we are far from the intensive application of autonomous robots integrating mobility, manipulation, and perception in a nonartificial environment and working under task-level programming.

In power electronics, the market for insulated-gate power devices, more specifically insulated-gate bipolar transistors, has consolidated, and the performance of these devices is improving. Also noticeable is the application of microcontrollers and high-performance digital signal processors in the control units of power electronics converters. Leading companies use specialized processors, mainly in high-performance electric drives. Smart-power technology is also growing in importance in low-power ranges up to, say, 200 W, in such areas as automotive electronics, telecommunications, and lighting.

On the negative side, there are increasing concerns about electrical pollution of the ac power distribution network, mainly generated by switched-mode power converters. Future regulations limiting this pollution will imply drastic changes in the design of power electronic converters, with a corresponding impact on their cost and volume, among other parameters.

Such other emerging technologies as fuzzy logic and neural networks are gradually entering the real industrial world.

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Power and energy

- ***Enthusiasm for efficiency***
- ***Coal cleans up***
- ***East meets West***
- ***Nuclear blues in the bloc***

In the electric utility industry, 1991 dawned with the hope that a number of difficult and vital policy issues would finally be resolved. Although dark clouds of war had gathered in the Persian Gulf, casting short-term uncertainty on oil supplies and prices, some saw a silver lining: that the conflict would spur industrialized nations to finally take a longer-term view of their energy needs and the fuels and technologies needed to meet them.

In the United States, for example, hopes were high that the country would soon have its first comprehensive National Energy Strategy in about 15 years. In Japan, a long-term nuclear plan encompassing generating-plant construction, fuel reprocessing, and long-term storage of high-level nuclear waste seemed eminently achievable.

In Europe, there was hope that European Community (EC) member countries would be able to agree on rules governing access to transmission lines—crucial to the buying and selling of electricity between different utilities and countries. There was also hope that EC-wide energy plans could be formulated to take into account potential economic opportunities in Eastern Europe, such as access to Soviet natural resources and the rebuilding of decrepit networks and generating stations—many of them nuclear—in the former Soviet bloc.

By year's end, however, with the Persian Gulf War over and oil prices stabilized, much of the optimism was gone. For example, the U.S. energy strategy, bearing the unmistakable stamp of then White House Chief of Staff John Sununu and other conservative presidential advisors, was accorded a chilly reception in the U.S. Congress, where it has languished since March.

DE FACTO POLICY. But despite this policy failure, progress—technical and otherwise—was made by utilities, local governments and their regulatory agencies, equipment makers, and others who, in the face of Government indecision, seized the lead and pushed ahead with plans of their own. In the process, they began forming *de facto* policies likely to affect the industry into the next century.

Glenn Zorpette Senior Associate Editor

For example, U.S. advocates of energy efficiency were bitterly disappointed by the proposed energy strategy's failure to set national standards for electric lights and their labels, remove taxes from sizeable efficiency rebates, and otherwise further their cause. "We would like to see more done on a national level," said Mark Hutchinson, an analyst in the demand planning department of the New England Power Service Co. in Westborough, Mass.

"Instead of us having to pay rebates every time customers buy high-efficiency appliances," he said, "it would be better if they had no choice but to buy high-efficiency appliances." (Although Federal efficiency standards cover a few appliances, many others are not scheduled to be covered for several years.) "But there is also a lot that states can do in the meantime," he conceded.

Indeed, in the northeastern and western parts of the country, utilities and state regulators have designed, or are designing, new financial models to allow utilities to increase profits by convincing their customers to reduce their energy needs (primarily through the use of more efficient lighting, appliances, machinery, and so on).

The Electric Power Research Institute in Palo Alto, Calif., estimates that by the year 2000 these utility efficiency programs could trim U.S. summer peak demand by 45 GW (about 6.7 percent), saving about US $45 billion over the period [see "Utilities get serious about efficiency," *IEEE Spectrum*, May 1991, pp. 42–43]. The programs are also expected to keep out of the atmosphere untold hundreds of thousands of tons of sulfur and nitrogen oxides, as well as many millions of tons of carbon dioxide.

HIGHLIGHTS

Success: World's first pressurized fluidized-bed combustion generating plant, a 70-MW facility built by American Electric Power Service Corp. of Columbus, Ohio, began generating electricity.
Shortfall: U.S. National Energy Strategy floundered after winning no support in Congress.
Notable: European utilities began considering how to integrate eastern and western power grids.
Newsmaker: António José Baptista Cardoso e Cunha, commissioner in charge of the European Commission's energy directorate, who called for freer access for third parties to the continent's multinational transmission grid.

Even greater emissions reductions were the goal of 1990 amendments to the Clean Air Act [see "Power and energy," *Spectrum*, January 1991, pp. 61-64). Although the first phase of the reductions is not scheduled to take effect until 1995, utilities faced a deadline last Dec. 31 for filing plans with their state public utility commissions, detailing how they intended to comply with the new regulations.

As of late October, however, only Allegheny Power System, headquartered in New York City, had managed to file its plan, according to an industry source. The utility, which depends on coal-fired plants to meet almost all of its demand, intends to rely heavily on advanced flue-gas desulfurization systems (scrubbers) to reduce its pollutant emissions, according to David C. Schmidt, manager of public information at Greensburg, Pa.-based West Penn Power Co., the main operating unit of Allegheny Power.

SCRUBBING COAL. Such scrubbers are one of the few options available to these utilities, noted Mary Kenkel, spokesperson for the Edison Electric Institute, the Washington, D.C.-based trade group representing investor-owned electric utilities. The impact of so-called clean coal technologies is not expected to be felt until the second phase of the Clean Air Act, after the turn of the century, Kenkel said.

Nonetheless, an important milestone was reached on Nov. 29, 1990, when electricity was generated in combined-cycle mode for the first time by American Electric Power's Tidd plant, a pressurized fluidized-bed combustion facility on the Ohio River near Brilliant, Ohio.

The 70-MW demonstration plant burns crushed coal mixed with dolomite, which captures more than 90 percent of the sulfur released by the coal [see diagram, p. 51]. Since combustion takes place at a lower temperature than in a conventional boiler, emission of nitrogen oxides are also reduced, to about 50 percent of current Federal limits. (Carbon dioxide remains a problem, but somewhat less so because of the relatively high efficiency of combined-cycle plants.)

The $185 million Tidd project received $60.2 million from the Department of Energy (DOE) under its Clean Coal Technology Program. In September, the DOE announced that it had selected nine other projects to add to the 33 already being supported, all by a combination of DOE, industry, and state funds.

Four of the nine new projects involve coal

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gasification technologies in one form or another and one of these, the Wabash River Coal Gasification Repowering Project in West Terre Haute, Ind., would account for nearly two-fifths of the entire $1.5 billion that the whole group is estimated to cost.

EAST-WEST INTEGRATION. While such advanced U.S. projects offered a look ahead, officials of the Commission of the European Community had to turn their attention to some of the most antiquated generating plants and electrical networks in the developed world: those in the former Soviet bloc. In July, Netherlands Prime Minister Richard Lubbers set up an international conference of 35 European nations to formulate a comprehensive energy charter for the group. A new secretariat within the European Commission's energy directorate, Directorate-General (DG) XVII, will look into the same issue.

The charter "should define the legal and administrative framework for closer cooperation between East and West," said Friedrich W. Kindermann, head of the electricity division in DG XVII. Specific areas being studied by the conference, Kindermann said, may include oil and gas sales, nuclear safety, training, electricity production and pricing, tariffs, and refurbishment of power stations. The group hopes to have a draft document outlining specific protocols by March 1992, he added.

The secretariat is not starting from scratch in the huge undertaking. Since 1989 the commission has been studying Eastern European networks under a program called Phare (from the French for Poland-Hungary Economic Renovation Assistance). Since then, the program has been extended to include Czechoslovokia, Romania, and Bulgaria. Later this year, Kindermann said, DG XVII will begin its "most interesting study. . .of exactly what will need to be done in each of those countries to stabilize their networks, so they can be connected to the Western network." (The Yugoslavian grid was integrated into the Western one several years ago.)

Not contenting itself with even this ambitious undertaking, the commission also proposed opening up the European transmission grid to third-party access. While cautioning that the long-term proposals have not yet been approved by the full commission, Kindermann said that they call for the abolition of monopolies on electrical production and on construction of transmission lines; the unbundling of utilities' generation, transmission, and distribution activities into separate financial and administrative divisions; and the right for so-called third parties to have access to grids.

However, continental utilities, which built and operate the transmission lines, oppose the proposals. Their objections are similar to those voiced by some U.S. utilities—essentially, that such lines are finite resources and that to open them to third parties would be to invite problems with stability and reliability. In Europe, however, the issue is greatly complicated by international-trade and geopolitical concerns, because most utilities are state-owned and operated.

'MOST DANGEROUS' REACTORS. The dissolution of the Soviet Union, meanwhile, presented Western Europe with a much more pressing problem: what to do about the dozens of Soviet-designed nuclear power plants in former republics and the Eastern bloc. Their reactors are often built to safety standards far less rigorous than those of Western reactors, and many plants lost their Soviet-trained operators and other forms of Soviet support last year.

Late last year concern was particularly high over the No. 1 and No. 2 reactors at Bul-

EXPERT OPINION: The electric utility business is shifting paradigms

CARL J. WEINBERG

The electric utility business appears to be in the midst of a major transformation—a fundamental shift that will change the way it will operate and serve customers.

Forces at play may alter the structure and form of the business. The major driver on the supply side is a shift from technologies based on economies of facility scale to those based on economies of mass production, and on the demand side, a shift from supplying a commodity to supplying a service.

Since the turn of the century, the utility industry has exploited the economy-of-scale philosophy. Ever bigger generating units produced ever cheaper electricity. Along with size came increased efficiency, which decreased cost.

'The economies of large-scale generation are being replaced by the economies of mass production.'

Thus utilities developed a "grow and build" strategy to meet ever-increasing electricity needs. But this strategy has run its course. Both a metallurgical limit and an increasing complexity came into play. Thermal efficiency has not risen and generating unit sizes have topped out at 1000–1100 MW.

The other change has been the utilities practice of demand-side management. This change has been reinforced by regulatory action in California, New England, and Wisconsin, where utilities are now allowed to make a profit delivering efficiency.

Utility management is now much more serious about delivering efficiency. The utility basically turns from a commodity supplier of electricity into an energy services supplier—from delivering electrons to delivering heat, light, and refrigeration.

The economies of large-scale generation are being replaced by the economies of mass production: the cost of more efficient lighting, appliances, and windows is reduced by making more of them.

Even supply systems are getting smaller and more economic: gas turbines in the 50–200 MW range, and gas engines in the 250–2000 kW range. With plants this small, it makes sense for them to be installed as close as possible to the customer.

Such an arrangement also cuts down on transmission and distribution investments. Residential generators in the 3–5-kW range are being tested, and a feeder or substation may well become a good location for smaller supply systems. If, in addition, energy efficiency efforts are specifically directed at the substation- or feeder-level and coupled to supply or storage, investments in substation equipment could be deferred or avoided altogether.

The business objective now becomes not providing electricity at the lowest cost, but managing assets so as to provide the *service* to the customer at the lowest cost.

This distinction may lead to a model of a future utility, in which the neat separation of generation, transmission, distribution, and usage no longer exists. Some generation may be located at a distribution substation or on the customer's premise. Service to a customer could combine reducing his consumption and locating supply nearby.

What results is increased consideration of the cost and delivery capability of distribution systems. Enabling technologies such as micro sensors, solid-state equipment, communications and control systems, coupling neural networks with fuzzy logic, will introduce intelligence into the distribution systems. Combining these technologies could lead to smart substations that communicate with customers, reconfigure themselves, diagnose equipment, and dispatch local generation.

The future direction of the electric utility business is changing. The paradigm of the large, central-station power plant connected by wire to each and every customer, based on the economies of facility scale and commodity production, is giving way to another paradigm based on economies of mass production and energy services.

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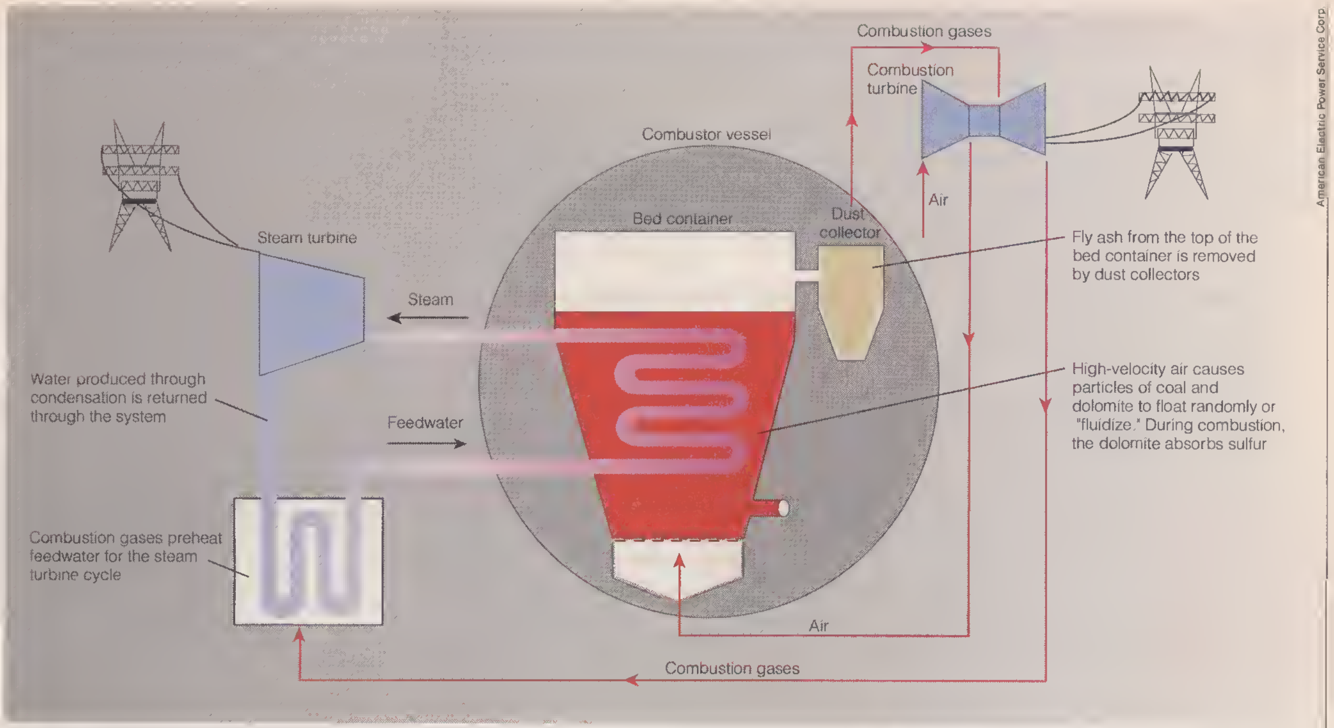

American Electric Power's Tidd plant, Brilliant, Ohio, combines pressurized fluidized-bed combustion with combined-cycle generation. The 70-MW demonstration plant uses exhaust heat from the combustion cycle to preheat feedwater for a steam cycle.

garia's Kozloduy power station, which a Bulgarian environmentalist, Lutchezar Poshev, said were two of "the most dangerous reactors in Europe, maybe the world" in an interview with London's *Financial Times*.

As of early December, one of the two 440-MW Kozloduy pressurized-water reactors (PWRs) had been shut down. But the other one and two other identical but newer units had to remain on-line; as a whole, Kozloduy supplies about 40 percent of Bulgaria's electricity. With the country depending on the plant to help heat homes in winter, many millions of dollars in technical help, spare parts, and equipment began pouring in from the European Community, the Paris-based Nuclear Energy Agency, and various U.S. organizations to avert what some felt could be an impending calamity.

Concern over accidents and older plants also surfaced in Japan and the United States, but it was a far cry from the situation in Eastern Europe. Last February at the Mihama plant in Western Japan, a small pipe in the PWR's primary cooling system ruptured and forced the first use in Japan of an emergency core-cooling system.

Although the amount of radioactivity released was a small fraction of the plant's permitted annual emissions, the subsequent public outcry focused on the fact that operators reportedly waited 50 minutes before shutting down the plant and 90 minutes before notifying local authorities [see "Japan's nuclear power tightrope," *Spectrum*, April 1991, pp. 77–80). Even before the accident, a Government poll found that 90 percent of respondents felt "uneasy" about nuclear power in Japan.

Nonetheless, last summer construction began northwest of Tokyo on two plants with advanced, General Electric Co.–designed boiling-water reactors. Also, Windsor, Conn.–based ABB Combustion Engineering Nuclear Power signed a $200 million contract to help design and supply two advanced PWRs for Korea Electric Power Corp. in Seoul. The Japanese and Korean plants, the first of the so-called evolutionary plants that feature some simplified safety features, are scheduled to go into operation in the mid- and late 1990s, respectively.

In the United States, short-term hopes for the survival of the nuclear industry are pinned on continued operation of existing plants, a few of which are entering their fourth decade. Last summer, the oldest of this group, the Yankee Atomic Plant in Rowe, Mass., became a symbol of the industry's determination to keep these plants on-line, and a focus of opponents' equally determined efforts to shut them down.

At Rowe and other aging plants, the central issue is the integrity of their steel reactor vessels. According to the Cambridge, Mass.-based Union of Concerned Scientists and other groups critical of nuclear power, these vessels have been dangerously weakened by constant bombardment by nuclear particles. After a curious reversal, the Nuclear Regulatory Commission (NRC), Rockville, Md., essentially agreed with this assessment and recommended on Oct. 2 that the plant be closed indefinitely.

Yankee Atomic Electric Co., which operates the plant for a consortium of New England utilities, voluntarily put the reactor in a standby mode. But in mid-October the Bolton, Mass.–based company "made a pitch to the NRC, on a technical basis, that we should get permission to restart," said William J. McGee, the company's spokesman. "Science, we firmly believe, is on our side."

Public opposition to nuclear plants has revived interest in an idea once dismissed as economically unfeasible: converting completed, or partially completed, nuclear plants to burn fossil fuels. On March 30, the William H. Zimmer Generating Station generated electricity commercially for the first time. Eight years ago, the plant was nearly complete as an 800-MW nuclear facility; it has been converted to a 1300-MW coal-fired station. The plant, jointly owned by Columbus Southern Power (a subsidiary of American Electric Power), Cincinnati Gas & Electric, and Dayton Power and Light, is on the Ohio River near Cincinnati.

ACTIVISTS ATTACK WHALE. Nuclear power was not the only target of activists last year. Public opposition also intensified over Hydro-Quebec's proposed Great Whale project, which would situate a 3168-MW complex of three power plants and two substations on the river of the same name in subarctic Canada. The plants would be built about 200 km north of the existing LaGrande complex east of James Bay, which already produces 10 300 MW.

Plans call for the provincial utility to build four dams, which would drive 11 turbines but also flood some 3400 square kilometers of an area inhabited by 15 000 native North Americans. The natives, mostly Cree and Innuit Indians, have strenuously opposed the proposal, arguing their case before various provincial agencies and in New York State, which would be the beneficiary of much of the hydropower. ◆

Consumer electronics

- ***Proposed U.S. HDTV transmission systems are under test***
- ***Cable operators eye compressed programming channels***
- ***Digital Compact Cassette and Mini Disc systems compete with DAT***
- ***Digital audio radio is coming***

Techniques of video compression and bit rate reduction were the linchpins of many key 1991 activities in consumer electronics. For example, these techniques feature prominently in the digital high-definition television (HDTV) transmission systems under test as candidates for a U.S. standard. Cable operators are also poised to apply them to their conventional National Television System Committee (NTSC) systems in order to squeeze extra channels into existing cables.

In digital audio, an attribute of human hearing known as masking, in which some loud sounds render softer ones inaudible, is being broadly exploited. Philips NV, for one, discards the unheard sounds to reduce the bit rates needed to record high-quality sound with its new Digital Compact Cassette (DCC) system. Sony Corp. does the same in its new Mini Disc system. And the technique is being applied in systems proposed for digital audio broadcasting and in multimedia applications in the personal computer and telecommunications fields.

U.S. HDTV TESTING. Technical evaluations of proposed advanced TV transmission systems at last got under way in July at the Advanced Television Test Center in Alexandria, Va. The first one tested was the Advanced Compatible Television System (ACTV) jointly sponsored by the David Sarnoff Research Center, NBC, N.A. Philips Consumer Electronics, and Thomson Consumer Electronics. The consortium supporting ACTV, the Advanced Television Research Consortium, is also developing a digital simulcast HDTV system that is scheduled for testing.

Other systems already tested are Narrow MUSE (from NHK, Japan Broadcasting Corp.) and DigiCipher (General Instrument Corp. and the American Television Alliance [ATVA], consisting of General Instrument Corp. and the Massachusetts Institute of Technology). Early next month, testing is to begin on Digital Spectrum Compatible (DSC-HDTV) from Zenith Electronics Corp. and AT&T Microelectronics. In June, testing will begin on the ATVA Progressive System from MIT and ATVA.

Ronald K. Jurgen Senior Editor

The proponent of each system must deliver and maintain a complete TV transmission system, both video and audio, operating in real time with no simulations. This prototype hardware should represent all the elements needed to encode and modulate a TV signal for transmission by a TV station, plus the actual hardware representing the TV receiver that would demodulate and decode the signal.

Laboratory testing of each system takes a minimum of seven weeks. It includes interference testing for co-channels (different services operating on the same channel number in nearby communities), adjacent channels (one service operating nearby on the next channel above or below the other service), and airplane flutter. Testing will also cover UHF taboo conditions (ruling out the location near one another of certain channel combinations between channels 14–70).

The laboratory tests focus, too, on the effects on each system of other impairments that can occur in transmission, such as various kinds of electronic and environmental noise, as well as the impact of ghosting (multipath transmission) caused by terrain or buildings in the path of the transmitted television signal.

Digital videotape recordings are made of each system's performance under the various interference and impairment conditions. Then the tapes are viewed by nonexpert viewers for subjective evaluation.

After the laboratory tests, the Federal Communications Commission (FCC) Advisory Committee plans field testing of the one or more systems deemed deserving from its laboratory performance. With the results of these tests, plus pertinent information on regulatory, legal, economic, and public policy matters now under evaluation, the committee will recommend to the FCC a system as a standard. The goal is to help the FCC set the new standard by June 1993.

HIGHLIGHTS

Success: Compression techniques revolutionized video and audio products and systems.
Shortfall: Digital audio tape had yet to appeal strongly to consumers even as competing products neared market introductions.
Notable: Digital audio broadcasting was proposed to enhance listening to the radio.
Newsmaker: Zenith Electronics Corp. used a two-level signal to cut interference and increase the reception area for its Digital Spectrum Compatible HDTV system, a candidate for a U.S. HDTV transmission standard.

HDTV ELSEWHERE. Meanwhile in Europe and Japan, HDTV also moves forward. The European Commission has issued a directive, which applies only to satellite broadcasting, encouraging the use of the D2-Mac standard (an interim enhanced-definition system based on a version of the multiplexed analog component signal) as a stepping stone to HDTV. The *Financial Times* reported Sept. 2 that the D2-Mac standard was strongly supported by the French and the Netherlands governments, and backed by manufacturers such as France's Thomson, Philips of the Netherlands, and Finland's Nokia.

In November Japan began broadcasting eight hours a day of Hi-Vision, the Japanese analog version of HDTV. Wide-screen NTSC television sets are on the market for Japan's enhanced-definition TV. Those behind Hi-Vision are also working on digital HDTV systems.

ENLARGING CHANNEL CAPACITY. A trend toward TV cable systems with higher channel capacities is developing in the United States. In the Whitestone section of Queens County, N.Y., for example, Time Warner Cable has changed from a 550-MHz, 75-channel cable TV system to a 1-GHz, 150-channel system. The upgrade involved adding optical-fiber cable from the headend in Flushing, N.Y., to Whitestone and replacing all the amplifiers in the leg of the system serving each neighborhood with at most four 1-GHz amplifiers. With fewer amplifiers, reliability improves and noise and distortion decrease.

But such upgrades are just the beginning and even more channels can be made available through compression techniques. Walter S. Ciciora, vice president, technology, American Television & Communications Corp., Stamford, Conn., described one possible way of getting more than 150 channels from 1-GHz systems. Speaking at the IEEE Consumer Electronics Society's international conference in Rosemont, Ill., in June, Ciciora depicted a 1-GHz system having ninety 6-MHz channels—60 for conventional NTSC programming and 30 for HDTV signals. Then if 5-to-1 video compression were applied to the remaining sixty 6-MHz channels, they could handle 300 compressed channels of programming—bringing the grand total to 390 channels.

Last September Cable Television Labora-

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tories (CableLabs), Tele-Communications Inc., and the Viacom Networks unit of Viacom International Inc. jointly issued a request for proposal with the goal of acquiring equipment for systems delivering digitally compressed programs. Later the Public Broadcasting Service, Alexandria, Va., joined the effort. The digital compression devices would let cable TV program suppliers bounce numerous program services off one satellite to cable TV headends.

DIGITAL AUDIO RECORDING COMPETITION. With digital audio tape (DAT) not yet a real presence in the marketplace, two competing systems have surfaced. One is the Digital Compact Cassette (DCC) from Philips Consumer Electronics, Knoxville, Tenn. The other is the Mini Disc System from Sony Corp., Tokyo.

The Philips system records a novel digital cassette and plays it and conventional analog cassettes. The DCC is the same size as an analog cassette. At the highest sampling rate, it records for 45 minutes in each direction (total 90 minutes).

The coding technology used is called precision adaptive sub-band coding (PASC) and is not compatible with that used for digital audio tape. It is four times more efficient (4:1 data reduction) than traditional pulse code modulation and is said to yield the equivalent of a compact-disc signal: a dynamic range of 18 bits or 108 decibels and a ratio of signal to total harmonic distortion, including noise, of 92 dB (less than 0.0025 percent). Frequency range is 5 Hz to 22 kHz. Sampling rates are 48, 44.1, or 32 kHz, depending on the digital source signal.

The audio frequency range is digitally filtered into 32 sub-bands. Then the PASC signal processor models the ear—or rather, the aural characteristics of the spiral coch-

EXPERT OPINION: HDTV continues hot

LEANDER H. HOKE JR.

High-definition television (HDTV) is the enduringly hot topic in the consumer electronics industry, especially in light of the ongoing testing of the proponents' systems at the Advanced Television Test Center in Alexandria, Va., a setup that has so far cost US $15 million.

With the cost to the consumer of proposed HDTV seen as remaining prohibitively high for the foreseeable future—possibly into the late '90s—TV set makers are developing alternative models that will give the viewing public some of the benefits without all of the costs.

The introduction of a 16:9 aspect ratio picture format, compared to the conventional 4:3, has already taken place in Europe, with Thomson CSF and Philips NV leading the way. In Japan several manufacturers have adopted the 16:9 format for their extended definition television sets to be used with the NTSC-compatible Clearvision terrestrial broadcast system. In the United States, Thomson has begun operation of a pilot plant for 16:9 cathode-ray tubes, with other tube manufacturers expected to follow closely behind.

'Digital Compact Cassette hardware is expected in the marketplace by late this year.'

Video compression is another technological benefit from HDTV activity. Use of these techniques in the future will markedly reduce the cost of distribution systems for video information. One satellite transponder or cable channel will carry five to 10 times as many independent signals as are carried today.

Over the past year, the number of TV stations around the country broadcasting closed-caption information has steadily risen. With the landmark vote on the closed captioning bill by the Congress and signing into law by the President last summer, all TV sets with screens 13 inches or more in diagonal and manufactured or imported after July 1, 1993, will contain a built-in captioning decoder. The hearing-impaired will be better able to enjoy TV and the tool could help teach young children and foreign-born adults to read. The original stand-alone decoders were in the $200 price range. Second-generation decoder ICs and the marriage with the TV set's on-screen display function will slash feature cost for the built-in decoder function.

Compact Disc Interactive (CD-I) recently introduced to the U.S. consumer market is an outgrowth of both the optical videodisc developed in the early 1970s by Philips and CD-ROM technologies developed in the mid-'80s by Philips, Sony, and others. By using a CD-I player and a conventional color TV set, one can gain reasonably fast access to large amounts of information. Low-cost software will encompass the fields of education, entertainment, and information with the user operating in an interactive mode, skimming for subject overview or delving deeply for mastery.

One CD-I disc can contain 650 megabytes of information, equivalent to 300 000 pages of text or 1000 floppy discs. Eastman Kodak Co. recently announced a CD-I compatible photo CD that can contain 100 separate images made from standard 35-mm negatives.

Digital audio tape (DAT) has reached a milestone in the United States with the passing of legislation to legalize its sale and use for private consumer audio taping. During the past year, new support for this technology was developed within the electronics, music, and recording industries based upon a series of agreements.

Each DAT machine will incorporate the Serial Copy Management System, which will allow an unlimited number of copies from a digital original but no digital copies from a copy. Modest royalty charges will be placed on new equipment and blank digital audio tape. The royalty fund will be administered by the U.S. Copyright Office and the Copyright Royalty Tribunal with distribution to music creators and copyright owners.

Another consumer audio product, Digital Compact Cassette (DCC), was announced last year by Philips, the developer of the original compact cassette. Hardware is expected to go on sale by late this year. Matsushita Electric Industrial Co. has joined forces to help in the development and manufacture of this new technology. DCC equipment can play analog as well as digitally recorded tapes. DCC tapes can be quickly duplicated on low-cost media such as conventional VCR tape.

After nearly 10 years of work on several fronts, the Electronic Industries Association (EIA) is ready to release the standards document on the communications framework (CEBus) for home automation. The industry, comprising diverse manufacturers of appliances and electronic convenience items, is moving closer to providing practical, interrelated products once viewed as items for the home of the future.

As new lower-cost generations of products are brought to the marketplace and prices fall, equipment once intended for office use has been transformed into consumer products. Cellular phones, paging devices, and home computers are recent examples. The tele-fax and home personal copier could soon be at this threshold.

U.S. factory sales of electronics improved over 1990, according to the EIA, with the consumer electronics area improving by 7 percent, thus signaling an easing of the recession.

Although TV set sales were lower than in 1990, the increase was led by VCRs, camcorders, and separate audio component equipment. As has been the case in most years since 1957, the relative cost of consumer electronics items again decreased compared to the U.S. annual consumer price index for all goods and services.

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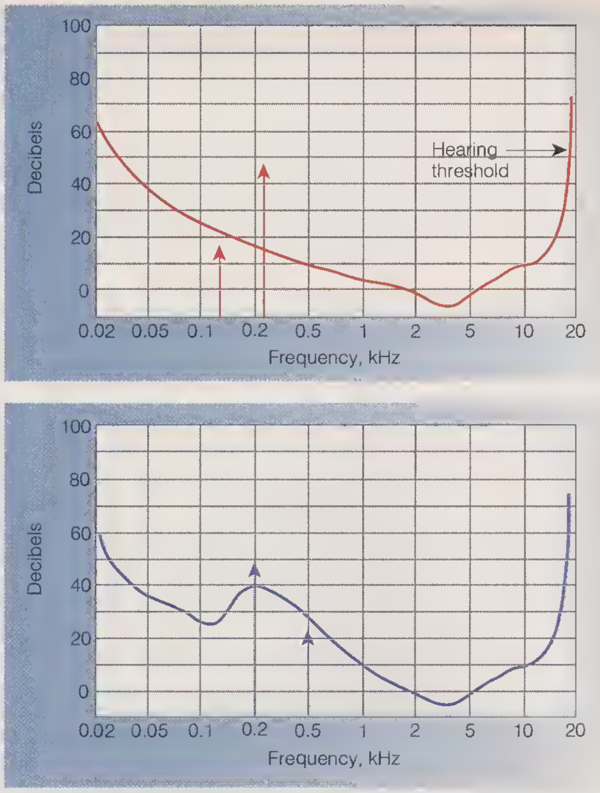
lea inside the ear—taking as its starting point the threshold of hearing of the most sensitive human ear. This threshold varies with frequencies, the ear being best at hearing middle-frequency sounds [Fig. 1]. As the sound is registered, the signal process continuously adapts to the dynamically varying threshold. Coding efficiency is increased since below-threshold (and inaudible) sounds are rejected.

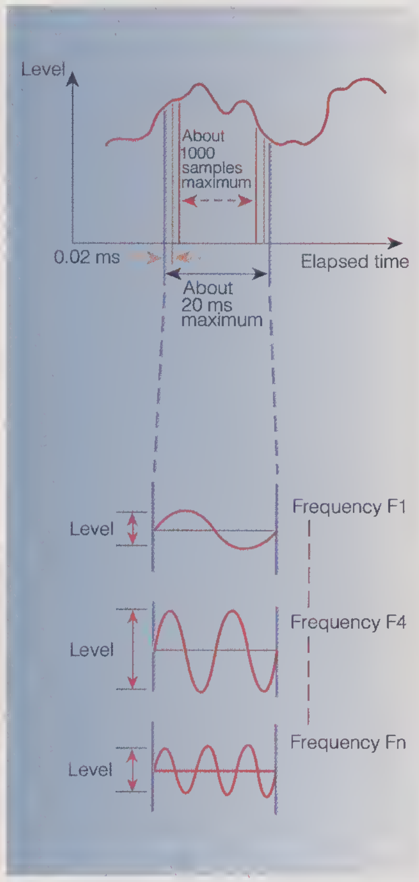
Every sub-band is allocated the bit capacity it needs. Any bits not required by particular sub-bands are reallocated to other sub-bands to optimize coding accuracy over the entire audio frequency range.

The PASC information, together with error correction codes, is multiplexed into eight channels for recording on eight 185-μm-wide tracks—one set of eight for the forward direction and a second set of eight for reverse—alongside sub-code data on an auxiliary track, all on a 3.78-mm-wide tape.

Sony's Mini Disc system produces about 74 minutes of digital sound on 64-mm magneto-optical disks (half the size of standard audio compact disks). A digital audio compression technique called adaptive transform acoustic coding (Atrac) is used.



[1] Philips Digital Compact Cassette uses masking to reduce bit rates needed to record high-quality sound. Only sounds above the threshold of hearing (top) are heard, even if they are soft. But if a loud sound precedes a soft one (bottom), the threshold is increased temporarily and the soft sound is masked. Since the soft sound no longer needs to be coded, extra information capacity becomes available for more precise coding of the loud sound.



[2] In Sony's Mini Disc audio recording and playback system, waveforms with 20-ms spacing are converted to frequency components. The magnitude level of those components is analyzed by an encoder, masking information is added, and then the signals are compressed fivefold.

As described in the July 1991 issue of the *Journal of Electronic Engineering*, the system digitizes the signal with a 44.1-kHz sampling frequency and 16-bit quantization. The Atrac encoder then converts the digital waveforms at 20-mm segments of about 1000 different samples [Fig. 2]. The encoder analyzes the magnitude of each frequency in the form of distribution at 16-bit stages. Next the system adds the minimum audible limit characteristics and masking effects plus other auditory effects geared to human listening abilities. The signals then undergo fivefold compression (5:1 data reduction).

In playback, the system produces a digital waveform with a 20-ms interval and the Atrac decoder regenerates the original signal by combining several hundred frequency components recorded on the disc. A key user feature is a 1-megabit memory that retains 3 seconds of playing time for noninterrupted playback under vibration and shock conditions.

To play back conventional optical discs, the pickup detects the amount of reflected light from the presence or absence of pits revealed on the disc surface by the laser beam. But during playback from magneto-optical discs, the pickup scans for recorded magnetic signals with a value of 1 or 0 during laser irradiation.

Depending on the direction of the magnetic signal, the polarization plane of the reflected light rotates slightly in the positive or negative direction (Kerr effect). A polarized beam-splitter sends the reflected light to two light-receiving elements, with the amount distributed proportionally to the positive or negative orientation of the polarization plane. Then the system calculates the difference between the light levels from the electrical output of the light-receiving elements and assigns a value of 1 or 0 to the signals.

Sony uses a recording technique called a magnetic field modulation overwrite system. It modulates the magnetic fields at fast speeds using the input signal to reorient the magnetic direction. The disc is positioned between a magnetic head and the optical pickup. The head moves in synchronism with the laser spot, with current to the magnetic head varying the magnetic field. The system controls the size of the marks recorded on the magnetic surface by inverting the periodicity of the magnetic field.

DATA COMPRESSION FOR RADIO. At the IEEE Media Briefing in New York City in October, Almon H. Clegg, president of CCi, a consulting firm in Rockaway, N.J., discussed the prospects for digital audio radio (DAR), which would use a data compression scheme similar to that in DCC and Mini Disc.

Clegg said that many broadcasting systems have been proposed for providing noise- or interference-free digital-quality audio but basically they are of three types: "new spectrum allocation, . . . as in the 1.5-GHz band, which requires FCC regulatory action; in-band, which uses the current AM and FM radio spectrum, but at different channel spacings than is currently practiced—digital may require a wider bandwidth than current analog broadcasting; and in-band and in-channel or, in other words, an FM broadcaster would simultaneously broadcast the analog and digital signal with the currently specified 200-kHz frequency spacing." ◆

Transportation

- **_High-speed and light rail expand worldwide_**
- **_Maglev shows promise for U.S. applications_**
- **_English Channel Tunnel runs into some problems_**
- **_Electric cars get a needed financial push_**

Despite widespread economic problems, the global transportation industry moved its rail, air, and automobile technologies forward. High-speed rail, for example, continued to be an active area in France, Germany, Japan, and the United States.

The French Government approved the French National Railway's (SNCF's) US $36 billion plan for a 4700-km extension of its Train à Grand Vitesse (TGV) network by the year 2010. Sixteen new lines [Table 1] will feed into the hub of the existing TGV network in Paris. A key part of the project is TGV Transalpin, which involves interconnection of the Rhine-Rhône, Sud Est, and Méditerranée TGV routes to provide a network that will link London with Turin, Paris with Rome, and Barcelona with Milan.

SNCF also has ordered 100 double-deck TGV trainsets from GEC Alsthom NV, Amsterdam, the Netherlands, to increase capacity on the Nord and Sud Est lines. According to the September 1991 issue of *Railway Gazette International*, each trainset is made up of two power cars and an articulated set of eight trailer cars. The lower deck of the trailer car that contains the bar and restaurant will house the bulk of the technical equipment for the entire train. Included will be low-voltage auxiliary converters, batteries, battery chargers, 550-kVA three-phase inverters, and forced ventilation for the equipment modules. An hourly rating of 8800 kW will allow train operation at 300 km/h.

In Germany, the state-owned railroad system inaugurated high-speed train service on a new line linking Hamburg, Frankfurt, Stuttgart, and Munich as well as cities in between. Two dozen trains capable of speeds up to 280 km/h, but averaging 150 km/h, will cut travel time over the 540 km from Hamburg to Frankfurt by 1 hour to 3.5 hours. The trains were built by a consortium consisting of ABB Henschel, AEG, Duewag, Dywidag, Hochtief, Krauss Maffei, Knorr Bremse, Krupp, LHB, Man GHH, and Siemens.

Ronald K. Jurgen Senior Editor

Meanwhile in Japan a new Shinkansen trainset has been designed to run at speeds up to 350 km/h and is scheduled to make its first trial runs in March.

In the United States, the state of Texas has awarded a franchise to the Texas TGV Corp. to build a $6 billion, 1000-km triangle linking key cities in the state. The first stage, connecting the Dallas–Fort Worth Airport with Dallas and Houston, is scheduled for completion in 1998. Links to Austin and San Antonio are to be completed by 1999. The trains are expected to travel at times at speeds up to 320 km/h with departures every 30 minutes (every 15 minutes during morning and afternoon peaks).

However, as in all potential high-speed corridors in North America, financing is the problem. Public-private partnerships are likely to be needed to generate the billions of dollars required for new infrastructure.

LIGHT RAIL ON A ROLL. In an article in the February 1991 issue of *IEEE Spectrum* ["A streetcar named Light Rail," pp. 54–56], author Jeffrey Mora of the U.S. Urban Mass Transportation Administration described light rail vehicles (LRVs) as those that "typically run along exclusive or semi-exclusive rights of way, which permit much faster running speeds. And, unlike a rapid transit line, which runs only on fully grade-separated rights-of-way, such as in tunnels or on elevated structures, an LRT [light rail transit] system can make use of several different right-of-way types."

Now Los Angeles and four neighboring counties in California are planning commuter light rail services on five new routes that will connect with the new metro and light rail network at Los Angeles Union Station. The August 1991 issue of *International Railway Journal* reported that the new routes, called Metrolink, should start operating this year. Further south, a commuter service is planned between the cities of Oceanside and San Diego.

San Diego is also expanding its light rail system to include the 39-km North Line, a portion of which is under construction between the city center and Cedar Street. The North Line, which also includes a 6-km extension to the East Line to Santee and an 18-km east-west Mission Valley Line, will connect to Del Mar this year and possibly north to Escondido and west to the airport by 1995.

FUTURE U.S. MAGLEV? A report released in October by the Office of Technology Assessment of the U.S. Congress concluded that both magnetically levitated (maglev) vehicles and high-speed rail show much technical promise as high-volume, intercity passenger modes in selected corridors up to about 800 km [Table 2]. But, the report stressed, "any system would require substantial infrastructure investment initially, although high-speed rail and probably maglev systems have low operating costs relative to other modes."

The only maglev system in revenue operation at present is a fully automated, short, slow system in Birmingham, England. The Birmingham Airport maglev is a shuttle that runs along a 620-meter-long guideway linking the airport and the railroad station.

CHUNNEL TROUBLE. The last of the three tunnels linking England and France was joined beneath the sea in June. That was the good news. The bad news came from many sources:

• The cost of the tunnel has risen from a November 1987 forecast of £4.87 billion to an October 1991 forecast of £8.05 billion (US $13.7 billion). Eurotunnel—the Channel tunnel operators—and Transmanche Link—the consortium of 10 construction companies building the project—each accused the other of being responsible for the huge increase in costs.

• When the tunnel opens in June 1993, British and continental railway companies will have no trains ready for passengers. The only trains using the tunnel then will be freight trains and a few shuttle trains that will carry cars and foot passengers between Folkestone and Calais.

• Technical and financial problems have delayed plans to build a fleet of special tunnel expresses linking United Kingdom

HIGHLIGHTS

Success: The French Train à Grande Vitesse planned a US $36 billion expansion that will ultimately connect London with Turin, Paris with Rome, and Barcelona with Milan.

Shortfall: The English Channel project reported tremendous cost overruns.

Notable: An Office of Technology Report gave a boost to prospects for future U.S. maglev systems.

Newsmakers: The U.S. Advanced Battery Consortium and the U.S. Department of Energy agreed to jointly research and fund a four-year $260 million project to develop advanced batteries for electric vehicles.

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provincial cities with Paris and Brussels. For example, railways in Europe use different technical standards, and their electric locomotives operate on different voltages. Even though track gauges are the same, continental trains are too wide and too high to fit Britain's bridges, tunnels, and stations.

• In France, construction of the high-speed line from the tunnel to Lille will not be completed by the time the tunnel is expected to open.

ATC ON SCHEDULE. Eurocontrol, the European Organization for the Safety of Air Navigation, Brussels, Belgium, reported to 30 European airlines in October that its programs aimed at alleviating air traffic capacity problems were on schedule. It also announced that the Central Flow Management Unit for western Europe will become fully operational by 1994. The Brussels-based unit will be responsible for balancing demand and available airspace capacity to reduce congestion to manageable levels in all the states belonging to the European Civil Aviation Conference.

In the United States, the National Oceanic and Atmospheric Administration (NOAA) has launched a program to help U.S. aviation make much more efficient use of the nation's crowded airspace. The Commerce Department agency, in cooperation with the Federal Aviation Administration, Washington, D.C., is attempting to multiply the number of flight weather information points throughout the country, with the goal of increasing them by at least fivefold on a test basis by 1994. The program is designed to improve accuracy, timeliness, and space resolution of weather situations affecting aviation.

The greater efficiency is made possible by recent advances in understanding meteorological processes, observation, and the processing and communication of weather information, said NOAA's Michael J. Kraus, who heads the aviation division of the agency's Forecast Systems Laboratory in Boulder, Colo.

Already a team of meteorologists and computer scientists has begun devising an aviation-gridded system that will allow forecasters to generate analyses and smaller-area forecasts of weather variables affecting flight. Kraus said NOAA believes that the system will produce better information in a test mode for cells every 15 km compared to the current 80-km nationwide grid.

In October the U.S. Advanced Battery

EXPERT OPINION: A year of bold starts

TRISTAN KNESCHKE

The passenger transportation industry is a cautious one—with due cause. It must carry safely and reliably millions of passengers every day. To ensure that safety and reliability, the installation of new equipment to overhaul or expand a transportation system is often preceded by years of development, testing, and verification. But last year the industry moved more rapidly than usual to embrace alternative and new technologies.

'Most transportation planners now realize that it is no longer possible to ease traffic congestion by building more highways.'

Potential developers of U.S. magnetic levitation (maglev) system technology, for example, got a boost from the U.S. Departments of Transportation and Energy and the Army Corps of Engineers. They jointly supported various studies of maglev technology assessment and concept definition. The purpose of the U.S. effort is to determine if maglev technology can be technically and economically viable in the United States, and to stimulate the development of a U.S. maglev system suitable for commercial application by the year 2000.

Concurrently with the U.S. government's efforts, Maglev Transit Inc., of Orlando, Fla., and a consortium of Japanese banks and German and Japanese corporations, plan a maglev system to link the Orlando International Airport with the tourist attractions on International Drive. It will be approximately 22 km long and use the German Transrapid technology with attractive-mode magnets. Its projected opening in 1996 would make it the first commercial high-speed maglev application.

Even though prototype maglev systems have been operating on test tracks in Japan and Germany for a number of years, technical and cost problems still must be ironed out. Neither country's system has yet proven to be capable of consistent, high-speed operation over prolonged periods of time. The Japanese system uses superconductors operating at thousands of amperes and, consequently, cost-effective methods must be found to limit the magnetic fields in the passenger and crew compartments. Germany's system operates with a 10-mm air gap between the vehicle and the guideway, making the maintenance of guideway alignment tolerances both critical and potentially costly.

Systems using conventional technology grow unabated. The French Government has approved the French National Railway's (SNFC) plan to build a 4700-km Train à Grand Vitesse (TGV) network by the year 2010.

TGV technology also is planned for use in the United States by the Texas High Speed Rail Authority to link Austin, Dallas, Fort Worth, Houston, and San Antonio with a system having approximately 1000 km of double track. Trains will run at a maximum speed of 320 km/h at 15-minute headways during peak periods and 30-minute headways off-peak. The projected cost of US $5.8 billion will be financed from private sources.

Also in Texas, two monorail lines totaling 32 km and a 7.6-km light rail line to cost $1 billion are planned by the city of Houston. The system will feature sleek vehicles running on a 0.6-meter-wide concrete beam elevated above the street traffic. The system, the first revenue service application of monorail technology in the United States, will resemble the one that has been used for two decades within Walt Disney recreation resorts in California and Florida.

Increased interest also has been shown in the electric trolley bus. While such cities as Boston, Oakland, Sacramento, and Vancouver studied how to best expand their existing systems, San Francisco ordered a new fleet of 35 articulated trolley buses.

In Los Angeles, $750 000 has been approved for a trolley bus study as part of the city's effort to install a new $2 billion transportation system. Electric trolley buses offer a smoother ride, a longer service life, and lower operating costs than diesel and alternative fuel buses. They are also more reliable and more environmentally acceptable.

A novel approach to solving transportation problems has been adopted in Pennsylvania. To resolve the ever-increasing traffic congestion along Interstate 95, the state department of transportation has initiated a 10-year, $10 billion project to integrate various transportation modes along the corridor. Instead of just widening the highway, the project will seek comprehensive solutions to the total transportation problem, considering such alternatives as exclusive lanes for priority vehicles, smart highway systems, and maglev.

Most transportation planners now realize that it is no longer possible to ease traffic congestion by building yet more highways. Transportation officials are beginning to respond to this challenge by selecting conventional and proven technologies as well as new approaches, and their decisions will have an impact well into the next century. If maglev proves to hold the key to solving part of U.S. transportation needs, the year 1991 will be remembered as the beginning of a new era in U.S. transportation.

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Consortium (USABC) and the U.S. Department of Energy (DOE), Washington, D.C., announced an agreement to jointly research and fund a four-year, $260 million project to develop a new generation of batteries for electric vehicles.

USABC is a partnership among Chrysler, Ford Motor, and General Motors, with participation from the Electric Power Research Institute. It was formed last January to develop advanced batteries capable of providing future generations of electric vehicles with much greater range and performance than is now possible.

Earlier in the year, Japan's Nissan Motor Co. said that it had built an electric car that could be fully recharged in 15 minutes, compared to the hour or more needed for other electric cars. But the Nissan vehicle, which uses a nickel-cadmium battery, has a range of just 160 km on each charge if driven at 72 km/h. Nissan subsequently announced that in the spring of 1993 it intends to market in Japan an electrically powered version of the Cedric/Gloria sedan that would have a range of 190 km.

Taking a different approach, the Southern California Edison Co. and the Los Angeles Department of Water and Power announced plans to build a road that uses magnetic induction to transfer electric energy from underground cables to cars and buses. The energy would be used not only to run an electric motor propelling the vehicles but also to recharge small batteries that would keep the cars running between electrified segments of roadway.

In the $2 million demonstration project, aluminum-stranded, rubber-insulated cables buried in the concrete of a 0.3-km length of road would create an alternating magnetic field above the surface of the road. Induction coils on the underside of the vehicle provide electromagnetic coupling and noncontact energy transfer.

1. Planned extensions for French TGV system

Line	Length, km	Cost, billion FFr: Infrastructure	Cost, billion FFr: Trains
Est	460	22.0	6.3
Transalpin	261	29.5	6.0
Rhine-Rhône	425	29.5	4.3
Provence	219	14.3	0.4
Côte d'Azur	132	8.8	1.7
Languedoc Rousillon	290	14.8	3.7
Aquitaine	480	22.2	0.9
Normandy	169	10.1	1.5
Midi-Pyrénées	184	8.7	—
Limousin	174	5.3	1.4
Grand-Sud	70	3.7	0.9
Brittany	156	5.7	0.8
Picardy	165	6.3	—
Auvergne	130	4.6	1.3
Interconnection Sud	49	3.1	0.2
Pays de la Loire	78	3.2	0.1

2. Proposed major U.S. maglev* and high-speed rail corridors

Corridor	Approximate route length, km	Technology	Overseeing authority	Status and cost
Orlando Airport–International Drive	22	Maglev	Florida Department of Transportation's Office of High Speed Transportation	Certified in June 1991; construction to begin by 1994, operation by 1996; US $5 million
Tampa–Orlando–Miami	840	High-speed rail	Florida High Speed Rail Transportation Commission	On hold because of lack of private investors; $6.8 billion from Florida plus additional private funding
Houston–Dallas–Austin–San Antonio	1000	High-speed rail[a]	Texas High Speed Rail Authority	Franchise awarded May 1991; $5 billion
Anaheim–Las Vegas	425	Maglev	California-Nevada Super Speed Ground Transportation Commission	Franchise awarded summer 1990; system construction in 1998; $5.1 billion
Pittsburgh–Airport–outlying communities	30	Maglev	Maglev Inc.	Construction of demonstration project to start in 1997; funding unresolved

* Maglev projects all by the German Transrapid International.
a The French Train à Grande Vitesse.

Source: Office of Technology Assessment, 1991

ILLINOIS TO USE IVHS. A public-private partnership to combat traffic congestion using intelligent vehicle–highway systems (IVHS) was announced in Schaumburg, Ill., in July. Called Advance (Advanced Driver and Vehicle Advisory Navigation System), the five-year project will be the largest field operational test of IVHS technologies in the world. Costing between $35 million and $45 million, it will be funded approximately 50 percent by the U.S. Department of Transportation's Federal Highway Administration, 25 percent by the Illinois Department of Transportation, and 25 percent by the private sector, including universities and Motorola Inc.

Advance is designed to provide the motorist with the best route to a desired destination based on current traffic conditions. The project will first equip a fleet of up to 5000 privately owned automobiles and commercial vehicles with on-board navigation and route guidance systems. Using Global Positioning System satellite receivers, the guidance system in these vehicles will be able to indicate their precise location. A traffic information center will report up-to-date traffic conditions to the in-vehicle system, which will then determine the best route to the destination.

In simple graphic displays and synthesized voice, step-by-step routing instructions will be presented to the driver.

The project will involve the northwestern suburbs of Chicago, including O'Hare Airport. Development of system components has begun, and equipped vehicles are scheduled to start operations early in 1993.

SOME FOR THE ROAD. Among the many automotive electronics developments unveiled last year were these:

- An optional solar-powered ventilation system was offered in the Mazda 929. It uses solar cells in the moonroof glass to run small ventilation fans to keep the car's interior from getting unbearably hot when the car is parked outside on hot days. On cool days, the solar-cell-generated electricity is automatically used to trickle-charge the car's battery.
- A fuzzy logic cruise-control system that maintains the set speed more accurately than conventional systems was made available in the Mazda 929.
- The V-TCS traction control system was an option for the Nissan Infiniti Q45. It combines a two-channel electronic traction control and a viscous limited-slip differential to obtain the benefits of both systems. The traction control keeps the driver from spinning the drive wheels while the limited-slip differential reduces the tendency to fishtail at low speeds.
- Lotus Engineering, Norwich, England, used a Citroen AX to demonstrate an active noise control system. Eight microphones pick up noise signals inside the car and feed this information to a digital computer. It in turn sends 180-degree out-of-phase signals to the car's multispeaker entertainment system. The result is cancellation of low-frequency noise.
- Saab Automobile AB, the Swedish car manufacturer, said it was developing a heat storage device called a thermo accumulator with Schatz Thermo Engineering of Germany. The unit accumulates heat transferred from the engine coolant and thereby allows the engine to remain at its normal operating temperature after it is shut off. The accumulator consists of a cylindrical container that includes a salt-based substance that changes state from a solid to a liquid at 78 °C. When in liquid form, the substance can store a large quantity of heat. The container is surrounded by an insulating shell and vacuum that allows heat to be stored for more than three days. ◆

Aerospace and military

- **New fighters and helicopters chosen**
- **Arms accords—maybe**
- **Is smaller better for space?**
- **Nexrad radar spots storms better**

War and tight budgets, revolt and political accord shaped military and space technology during the past year.

The six-week Persian Gulf War last winter tempered some calls for draconian military cutbacks and boosted prospects for high-technology and antimissile defenses. The abortive Soviet coup in August, however, prompted calls for even more drastic defense reductions. This came amid a major strategic arms treaty between the nuclear superpowers in July and a unilateral call in September by President Bush to slash the U.S. tactical nuclear arsenal. The developments cheered one group of atomic scientists so much that they set their "doomsday clock" back to 11:43, the farthest ever since its founding in 1947 from the midnight mark of nuclear annihilation.

Among several key milestones the U.S. military passed to modernize the armed forces for the next century were decisions on the next generation of Air Force fighter and Army helicopter. The Pentagon canceled a large new Navy fighter program because of cost and schedule problems, and it also acknowledged prospects of further downsizing. But the drive for modernized, "leaner, meaner forces," as described by Air Force Secretary Rice, appeared to remain strong. Downsizing was also a theme in civilian space activity last year—from the space station Freedom to a network of earth surveillance satellites.

ARMS CONTROL. This year continued the trend for political arms control agreements—unilateral and bilateral. These pacts affect military development in decreasing not only the gross quantities in inventory, but also the number of older systems needing electronics upgrades in the field; often older systems are retired.

No sooner had the Strategic Arms Reduction Talks (Start) agreement been signed in July—the first pact actually to reduce, rather than place ceilings on, intercontinental weapons—than calls came for more drastic strategic nuclear cuts. According to the Congressional Budget Office, Washington, D.C., the United States spent US $51 billion on nuclear offensive arms in 1990. The complicated Start agreement, which holds each arsenal to no more than 6000 intercontinental missile warheads and also limits nuclear bombers and cruise missiles, will cut those costs by several billion dollars. In a recent analysis, the Congressional Budget Office showed how to get more savings under various scenarios by cutting strategic offense costs as well as some in strategic defense [see table, p. 60].

John A. Adam Senior Associate Editor

Perhaps the Gulf War's greatest immediate effect on military technology was to boost work on antimissile defenses. Congress increased its funding for the Strategic Defense Initiative by more than $1 billion to $4.1 billion in 1992. More remarkable, though, was the political breakthrough that opened the way for fielding a limited missile defense in North Dakota by 1996. The first test of the Star Wars missile last January destroyed an incoming dummy warhead over the Pacific.

Although the definition of strategic versus tactical aircraft is blurring—the B-52 bomber carried out tactical missions in the Gulf War while the F-117A fighter conducted strategic sorties—the B-2 bomber is having trouble finding a mission for itself because of its high cost. Congress approved money for several of the flying-wing planes, but the future of a long production run for them was left in doubt.

NEW AIRCRAFT. A few traditional Air Force and Army tactical programs passed benchmarks last year, but not until after the services had pared them down.

Following a flyoff competition, the Air Force on April 23 selected the F-22 to be its air superiority fighter of the next century, a contract potentially worth $98 billion for 648 aircraft. A team of Lockheed, Boeing, and General Dynamics won the flyoff over the YF-23 entry by Northrop Corp., Los Angeles, and McDonnell Douglas Corp., St. Louis, Mo..

At a press conference in April, Air Force Secretary Rice said the Soviet's MiG-29 and Su-27 and France's Mirage F1 are "aerodynamically competitive" with the F-15, the current U.S. air superiority fighter, which became operational in 1974. By the early 2000s, he continued, when the F-22 is to be fielded, the United States may no longer have a big lead over potential adversaries in avionics and pilot training.

After flying 74 sorties over 91 days, the YF-22 beat the YF-23, which flew 50 sorties over 104 days and chose not to fly at very high angles of attack nor to fire any missiles. While the Northrop YF-23 design was more unconventional, emphasizing stealth and speed, the Lockheed YF-22 plane stressed a more balanced and traditional approach, one concerned as well with agility, reliability, and maintainability. The result is a plane that can be lethal not only beyond visual range but within sight of the enemy as well—an agility required in visual dogfighting, which was deemed important for the next century.

The aircraft's radar will benefit from an active, electronically scanned array antenna designed to operate in some 25 modes and at much longer ranges and reduced visibility to the enemy. It is being developed by Texas Instruments Inc., Dallas, and Westinghouse Electric Corp., Pittsburgh. General Dynamics Corp., St. Louis, Mo., will provide the plane's electronic warfare system and communications navigation system.

The F-22 will be more software-intensive than other planes and incorporate very high-speed integrated circuitry (VHSIC) and active-matrix liquid-crystal flat-panel displays. All weaponry is to be carried within the plane to increase stealthiness. Its engine benefits from thrust-vectoring, in which hydraulically activated nozzles control the engines' thrust to 20 degrees in two dimensions. Developed in a test program at Wright-Patterson Air Force Base, Dayton, Ohio, thrust-vectoring greatly increases maneuverability.

COMANCHE PROJECT. On April 5, the U.S. Army ended a six-year competition and picked Boeing Helicopter Co., Philadelphia, and Sikorsky Aircraft, Stratford, Conn. (a division of United Technology Corp., Hartford, Conn.), as the prime contractors for a projected $34 billion program for 1292 Comanche reconnaissance attack helicop-

HIGHLIGHTS

Success: Information-intensive military systems proved awesomely lethal in Operation Desert Storm.

Shortfall: The recently signed Start arms control treaty between the nuclear superpowers seemed dated already.

Notable: Final industry teams were picked to build the top military aircraft and helicopter of the next century.

Newsmaker: Iraq's Saddam Hussein showed remarkable resilience and defiance despite the modern forces and detection systems allied against him.

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EXPERT OPINION: Dramatic changes loom for the defense infrastructure

THOMAS L. FAGAN JR.

A host of changes occurred within defense and aerospace technology during 1991. The Persian Gulf War notwithstanding, the budget of the U.S. Department of Defense (DOD) without a spur like a Soviet strategic threat continues to shrink by about 4 percent a year. In 1995 it will be down 35 percent from the 1985 budget.

However, the infrastructure to support a 1985 budget is still largely in place. Defense spending is at its lowest share of the gross national product since before World War II. This year, therefore, will be a time for the DOD and the National Aeronautics and Space Administration (NASA) to regroup, rethink, and get a firm grip on the investment required for 1994-95 and beyond. Change will not be overnight, but dramatic nonetheless.

The Armed Forces will be totally restructured, with associated force reductions. Threats have changed, missions have changed. A European scenario is now one of quick reaction and crisis management.

Laboratory consolidations are also apparent. In Secretary of Defense Dick Cheney's testimony before the Senate Armed Services Committee, he stated, "Rather than develop technologies on a piecemeal, item-by-item basis, we are identifying linkages between technologies within and across systems. Developing technologies in clusters lays the foundation for system engineering, which can be carried out in parallel with component R&D. Military effectiveness and affordability goals are kept in sight while pursuing an integrated program of developments." Deputy Defense Secretary Don Atwood believes laboratory consolidation alone will save up to 30 percent of defense R&D costs.

The liberal side of Congress is developing a mind-set on R&D spending caps. Their premise is that without a technology driver from "the other side," there is no technology threshold to leapfrog. Thus, with no step-up of technology levels required, the United States does not need a technology push; ergo, a cap.

On the conservative side, Congress is trying to discriminate between a technology base and full-scale development. It supports growth in the technology base and modernizing selective systems.

What is the industry response to the disappearance of the Soviet threat—as well as to the economic change in Europe and to the realization that future DOD spending will be dictated by unknown international influences? The trend at this point is obvious. There will be more consolidations and expansions into an already crowded international arena by companies that need to "fill up the bathtub." Unfortunately, most of these firms lack the required experience.

Smart companies are pursuing joint ventures. Such efforts help risk-sharing, flesh out a technology fit, improve customer perceptions, and, most importantly, foster cost-sharing.

Other companies are sticking to their knitting. They are afraid of acquisitions. Although they feel that defense contracts are burdensome, they strongly believe that most defense firms do not make the transition well into nondefense areas. They carry too much baggage and superstructure with them.

'The infrastructure to support a 1985 budget is still largely in place, while defense spending is at its lowest share of the gross national product since before World War II.'

Regardless, the already shrunken defense supplier base will get even smaller. Further, the Defense Department is showing little inclination to protect any industrial base.

For the survivors in the defense business, diversification is a byword. It is also cheaper and faster to buy technology than to develop it. Companies with a large technology base can exploit that base by picking up the bargains currently on the market. They are trying to consolidate, improve productivity, wave the TQM (total quality management) banner, buy up capacity, improve their backlog, and hopefully maintain or increase their profits.

For a defense and aerospace contractor, where to put its chips becomes increasingly more important. In the current environment, it must be more narrowly focused and a niche player.

Defense electronics is a good niche. Given the declining budget, though, the DOD will be buying fewer platforms and weapons systems—fewer ships, planes, and tanks.

The real issue is: can the military get there fast enough with what it already has? But these existing platforms and systems will continue to be improved by product improvements, block changes, technology insertions, and service life extensions. Hence, the defense electronics business is likely to be more stable and, in the worst-case scenario, a flat business.

Some analysts, including International Defense Technology Inc., Washington, D.C., predict a significant improvement in defense electronics with an increase of up to 38 percent by the year 2000. Many subniches are especially good. The trend is certainly away from the strategic and toward tactical programs.

The hottest areas appear to be information systems, system integration, secure communications, electronic combat systems, C^3I, and the intelligence arena. Simulation and training should continue to be a cost-efficient way of maintaining readiness despite a tight budget. And software remains a vital, though usually the weakest, area for most defense contractors, who have not yet figured out that whoever controls the software and the interfaces, controls the system and the program.

Across these niches, the trend continues to be away from fixed-price development contracts and toward more conventional R&D cost-plus contracts.

Of course, the aerospace side of the equation has its own unique set of problems and difficulties: the Administration policy change to rely more on unmanned than manned launches, the cap on the space shuttle fleet, the throttling back of the Space Station, the rift between space science and space applications, and the uncertain future of earth observation-landsat systems.

These problems are compounded by increased competition and increased capacity, both domestic and foreign. Clearly, at this point aerospace will not be the benefactor of a peace dividend, if indeed there is one.

Many correctly point out that the space program lacks a nationally mandated goal like President Kennedy's mission of placing a man on the moon in the decade preceding 1970. We have not been back to the moon in 21 years and see no reason for it. The naysayers facetiously point out the need to be patient: Columbus discovered America in 1492, but the first permanent English settlement was not established until 1607.

It is true that NASA's in-house technical and management skills have eroded over the past two decades. But this problem can be fixed by changing some laws and regulations and the salary structure. What is required is what has always been required—a good public relations campaign to continuously educate the public on the benefits of space for all mankind here on earth.

In summary, regardless of all the pulling and tugging—and the many pressure points in this multivariate problem—the defense and aerospace market remains one of the largest in the United States. It is a good, challenging business—dynamic and exciting—and the advanced technology dimension makes it all the more fascinating for those who survive.

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ters. The losing team was McDonnell Douglas Helicopters, Mesa, Ariz., and Bell Helicopter Textron Inc., Fort Worth, Texas.

Formerly called the light helicopter (LH)—of which some 4500 were to be ordered at a total cost of $66 billion—the Comanche project was subsequently simplified. For instance, a copilot was added to reduce demands on automation. Key to the new helicopter is the ease with which it can be reconfigured for various missions, such as attack, air combat, armed reconnaissance, and long-range flights, and its ease of maintenance.

The Army estimates that the Comanche can be maintained with only 60 percent of the personnel currently required for the light helicopter fleet. Life cycle costs also will be cut by 40 percent, according to *Army Magazine*, with a ceiling of $702 per flight hour for parts and maintenance.

Among the manufacturers providing parts for the aircraft is Martin Marietta Corp., Bethesda, Md., which will supply two conformal forward-looking infrared sensors (flirs)—one for night vision and the other for targeting. A Westinghouse system will aid target detection and classification, and overseas, Germany's Messerschmitt-Bölkow-Blohm GmbH in Ottobrunn will work on a bearingless composite main rotor having blades that can be physically twisted rather than pivoted with hinges to vary lift.

Since the Comanche is a helicopter designed to be stealthy, it has minimal protuberances and specially designed exhaust and noise diffusion systems. The design also emphasizes deployability: the Comanche will be able to deploy within 30 minutes from a C-5 or C-17 transport plane. Eight Comanches will fit into a C-5.

The Army based its contract decision, initially worth $2.8 billion, on a seven-month evaluation of proposals. The first prototype is scheduled to fly in August 1994.

The Navy was not as fortunate with its major modernization program as the Air Force and the Army. On Jan. 7 last year the Pentagon canceled the Navy's A-12 Avenger program for 620 stealthy attack jets. At $52 billion, it was the largest contract ever canceled by the Pentagon. The deal was the extension of an initial January 1988 Navy contract with General Dynamics and McDonnell Douglas to fully develop eight largely composite, triangular aircraft for a fixed price of $4.8 billion.

Defense Secretary Cheney said the contractors' default was "based on the inability. . .to design, develop, fabricate, assemble, and test A-12 aircraft within the contract schedule and deliver an aircraft that meets Pentagon requirements." In case the message was not immediately clear to the aerospace and defense community, Cheney spelled it out. "No one can tell me exactly how much more it will cost to keep this program going," he said. "And I do not believe a bailout is in the national interest. If we cannot spend taxpayers' money wisely, we will not spend it." The next day, General Dynamics fired 3318 workers—including over 2000 engineers—on the highly classified project. McDonnell Douglas gave notice to an even larger number of employees.

Making its first test flight last year was the C-17, the large Air Force cargo plane designed to combine long-distance capabilities of the C-5 and C-141 with many of the short-runway capabilities of the C-130. McDonnell Douglas is to supply 120 C-17 aircraft, capable of lofting 87 metric tons of cargo, in the $35 billion program.

Also last year the Gulf War showed how electrotechnology has permeated many areas besides big weapons systems. It will affect even more areas once planned new technology is put into place. Because dropping supplies from the air is safer if conducted from either extremely low or extremely high altitudes, the Air Force is examining low-altitude drop systems from, say, 90 meters that use synchronized retrorockets with laser altimeters to slow the descent of packages from about 25 m/s to 2.5 m/s.

Combat helmets, too, are due for changes. In October the newsletter *Tactical Technology* reported contract awards for a helmet for special operations units. It will include interface modules for a global positioning system and/or compass and a mounting assembly for new night vision goggles.

Buoyed by new technical advances and a critical role in Desert Storm, night vision and electro-optics displays and goggles will grow steadily into a $1.4 billion annual market by 2001, according to a Washington, D.C.-based Electronic Industries Association survey. Among developments will be the combined use of thermal and image intensifier systems, a gradual acceptance of infrared search and track systems for air defenses and fixed-wing aircraft such as the F-14-D and the F/A-18, and newer materials such as mercury cadmium telluride detectors.

CIVILIAN SPACE. In September the space shuttle lofted into orbit the first eight-metric-ton, $710 million earth observing system (EOS) satellite, the largest vehicle ever built to monitor the environment. It could be the last of a dying breed. NASA already announced plans to reduce costs of the EOS program, from $30 billion to some $25 billion, by orbiting greater numbers of less sophisticated satellites. Rather than six large satellites, as many as 18 smaller ones would be in orbit.

Based on meetings held in July and August of 60 space experts who agreed that access to space would be better served by smaller, more numerous projects, NASA is also scaling back some other large projects.

The space station, after nearly $6 billion over seven years, received its full funding request of $2 billion from Congress last year and will be built, but on a reduced scale that is to save $6 billion from an estimated $40 billion in costs over this decade. Rather than a $10 billion Mars Rover Sample Return mission, in which one probe would make a round trip between planets, now the space agency is planning a host of small Mars landers that over many years would form a permanent sampling network transmitting data back to earth.

Expected to improve hazardous storm warnings and help coordinate air traffic are several next-generation weather radars, known as Nexrad, which began operation last year in Oklahoma, Florida, and the Washington, D.C., area. Built by Unisys Defense Systems Inc., McLean, Va., the far-ranging Doppler radar, with advanced processing and displays, passed an operational assessment in Oklahoma City early in the year.

The first 10 systems in the radar's limited production phase are scheduled to be operational by mid-1992. Plans call for an eventual network of 175 new weather radars. ◆

Arms reduction and U.S. missile defense options

Plan or option	Warheads: Strategic	Warheads: Theater	Deployed strategic defense	Annual savings compared with Administration's plan, in billions of 1992 U.S. dollars
U.S. forces as of early 1991	12 900	10 000	None	—
Administration's projected stance				
Administration's current plan	11 500	7 500	GPALS, Phase I	—
Administration's plan modified with Start treaty	10 500	7 500	GPALS, Phase I	—
Options after Strategic Arms Reduction Talks (Start) Treaty				
1. Ban heavy ICBMs, limit defense	10 500	7 500	GPALS, including space-based interceptors	2.3
2. Reduce strategic warheads to 6000	6 000	4 000	GPALS, no space defense	9.3
3. Reduce strategic warheads to 3000	3 000	2 000	One-half GPALS, no space defense	15.5
4. Reduce strategic warheads to 1000	1 000	0	One-eighth GPALS, no space defense	17.4

GPALS: Global Protection Against Limited Strikes
Source: Congressional Budget Office

Medical electronics

- **Monitoring blood gas in real time**
- **Fast temperature readings by ear**
- **Interest revives in artificial heart research**
- **Watching the human brain recall words**

Progress in medical electronics was evident on a variety of clinical and research fronts holding out the prospect of improved health care.

One noteworthy advance was in blood gas monitoring used to assess the cardiovascular, respiratory, and metabolic performance of patients during surgery and in emergency situations. It is now possible to do such monitoring in real time with the PB3300 intra-arterial blood gas monitoring system developed by Puritan-Bennett Corp., Overland Park, Kan., which will offer the system later this year. Among other companies expected to market such units are Optical Sensors for Medicine, Abbott Laboratories, C.R. Bard, and Pfizer.

In the PB3300 system, special sensing fibers are part of a microprocessor-based unit. The sensor [see illustration] contains three small optical fibers, each about the diameter of a human hair, and a thermocouple in a biocompatible package. The entire sensor is small enough to be inserted into a radial artery through an arterial catheter less than 1 mm in diameter.

Each optical fiber has at its tip a special fluorescent dye. The dye on one fiber is sensitive to partial pressures of oxygen, to partial pressures of carbon dioxide on another, and to hydrogen ion concentration on the third. (Engineers at the National Institutes of Health developed the first probes of this type.) The high-energy photons in light sent through the fibers by the system are absorbed by the dyes. They then re-emit the light at a different wavelength and intensity. Depending on the particular dye, the intensity of the re-emitted light is changed by nearby concentrations of oxygen, carbon dioxide, or hydrogen ions. This change is converted by the instrument to readings of partial pressures of O_2, CO_2, and pH.

The thermocouple measures blood temperature in the radial artery which is then displayed along with the blood gas values.

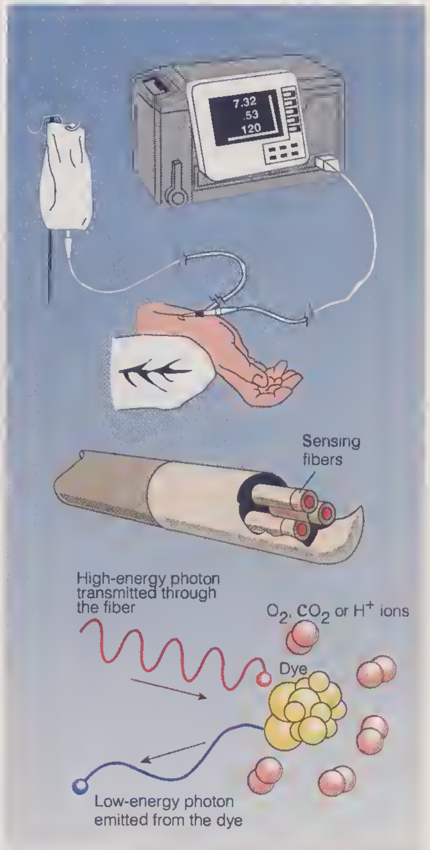
Even the mundane task of taking a patient's temperature benefits from modern technology. Introduced last year was a new tympanic or ear thermometer that measures infrared heat generated by the eardrum and surrounding tissue and displays the temperature in about 2 seconds.

Manufacturers include Diatek, IVAC, Thermoscan, Exeregen, and Intelligent Medical Systems. The thermometers sell for US $350–$600 and require a single-use disposable probe cover costing a few cents.

SUPPORT FOR THE ARTIFICIAL HEART. In July, the Institute of Medicine, Washington, D.C., released a report, "The Artificial Heart: Prototypes, Policies, and Patients," which calls for the National Heart, Lung, and Blood Institute (NHLBI) to continue research contracts in artificial heart technology beyond their expiration dates in 1993. The continuance, the report said, should be for an interim period to support work on ventricular assist devices and the total artificial heart. NHLBI is the only U.S. government source of funds for artificial heart research.

In 1988 research contracts on the total artificial heart were suspended after NHLBI decided the money would be better spent for research on ventricular assist devices, which were further along in development. That decision met strong resistance from congressional leaders and other officials and was later rescinded.

The first model of the total artificial heart is not likely to be approved by the U.S. Food and Drug Administration before the year 2005. Ventricular assist devices should be available by the late 1990s. Clinical trials on a long-term, fully implantable unit are scheduled to begin this year. Units are typically implanted in the abdomen, connected to tubes through which the blood is drawn from one of the heart's ventricles, and pumped into the circulatory system.



The intra-arterial blood gas monitoring system from Puritan-Bennett Corp. uses dye-tipped optical sensors. Light intensities, re-emitted from the dyes, are proportional to the concentrations of nearby oxygen, carbon dioxide, and hydrogen ion concentrations.

What complicates the funding issue is the uncertainty as to whether the cost of a total artificial heart will ever fall into line with the benefit to the patient.

VIEWING THE BRAIN AT WORK. Last year reports on the first images of the human brain as it performs the simple task of recalling a word revealed some surprises. The research, led by Marcus Raichle of Washington University in St. Louis and Larry R. Squire of the University of California at San Diego, was done in 1990 and 1991 and reported last November at a conference of neuroscientists. The images showed that the recall process was going on in unexpected parts of the brain, not just in the hippocampus.

In the experiments, 18 volunteers were

HIGHLIGHTS

Success: An intra-arterial blood gas monitor that displays in real time partial pressures of oxygen and carbon dioxide, hydrogen ion concentration, and temperature was unveiled.

Shortfall: The push to use lasers for cutting and coagulation in laparotomy and cholecystectomy lost ground to electric cautery.

Notable: The Institute of Medicine in the United States urged that development of the artificial heart be continued.

Newsmaker: Neuroscientists announced that PET images show unexpected areas of the human brain are activated when recalling words.

Ronald K. Jurgen Senior Editor

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seated with a positron emission tomography (PET) scanner placed around their heads. Injected into their bloodstreams was water with the oxygen molecule altered to make it a positron emitter with a half-life of 123 seconds. It provides a marker of regional cerebral blood flow.

When brain cells become active, they use more energy than usual. The energy demands are met by increased blood flow in those brain regions that are active. The increased concentrations of blood in those areas show up on the PET scan as hot spots.

Volunteers were presented first with a list of about 15 words on a TV screen. After a few minutes, a list of 20 word beginnings would appear on the screen in front of them, and they were asked to complete the word beginnings by saying the first word that came to mind, or by trying to complete the word beginning with a word from the studied list.

The PET images showed that the automatic form of word completion involved activity in the visual area in the back of the brain and that conscious recall involved activity in a spot in the frontal lobe of the brain and in the hippocampus. ◆

EXPERT OPINION: Incremental progress may take years of research and development

DOV JARON

Some strides made in biomedical engineering last year that involved both devices available for clinical applications and innovations still in the research phase have profound implications for the practice of medicine and the quality of life.

Among the many developments that occurred, here are a few that are already changing the delivery of health care or are likely to do so in the near future.

One important advance was the gathering of information about the chemical composition of blood. Such information is essential for the diagnosis of many clinical disorders. Conventional blood analyzers, which provide this information and are available in doctors' offices, clinics, and hospitals, test a sample of the patient's blood.

By this means, information is obtained only at discrete and infrequent intervals. But under certain clinical circumstances, it is important to closely follow changes in blood chemistry—either at frequent intervals or continuously. During open heart surgery, for example, a device placed into the arterial and venous lines of a heart-lung machine provides readings of blood oxygen and carbon dioxide content, pH, and temperature. But no device for direct measurement in a patient's artery had been available.

'Recent advances in the application of polymer science to biosensors appear to hold great promise.'

Now a new system is capable of measuring these parameters continuously using an optical-fiber catheter inserted directly into an artery. The device, approved for marketing by the Food and Drug Administration (FDA), is usable over long periods of time. It could revolutionize the clinical management of certain groups of patients. Other companies are expected to develop similar devices.

The most critical element in any measurement system is the sensor. This is especially important in the measurement of properties of a biological sample since the living environment is extremely hostile to foreign materials. Researchers for years have been seeking sensors that can be stable, sensitive, highly specific, and long-lasting in the living environment. One important need is a real-time glucose sensor that can be used in a closed-loop system for automatic delivery of insulin to diabetics.

Recent advances in the application of polymer science to biosensors appear to hold great promise. For example, polymers can be used to change the way in which the sensing compound interacts with the molecule of interest, such as glucose. Tightly coupling the sensing compound to the sensor electrode increases its longevity. In addition, the properties of the polymer can be adjusted to increase the rate at which glucose molecules diffuse to the sensor, thereby increasing the sensitivity and the responsiveness of the system.

Polymers may also be designed to increase specificity. For example, they can be formed to filter out molecules above a certain size, thus making the sensor specific only to smaller molecules. While still in the research phase, these polymer materials are likely to transform the field of biosensors.

Contrast agents, which enhance X-ray images of internal body structures, have been used in the clinical setting for decades. Recently paramagnetic compounds have been used to improve magnetic resonance images and now certain agents that show potential for enhancing ultrasound images are beginning to appear on the market. The contrast agent increases reflection of the ultrasound energy by creating an interface between the living material and another element such as air. Reflection occurs at the interface.

In practice, air bubbles, or particles containing air bubbles, are injected into the blood stream. The bubbles create multiple reflections that serve to enhance the image. To design an effective contrast agent, the air-containing particle must be compatible with blood, must be excreted in a reasonable time without harmful effects, and must remain in the system long enough to produce the enhanced ultrasound image. A contrast agent using air-filled human serum albumin particles was recently approved by the FDA for clinical use. While intended at first to improve images of anatomic structures in the heart, future applications of this and similar agents could be used to improve measurements of perfusion to critical organs, such as the coronary circulation.

One area of medical technology receiving a great deal of public attention in recent years is the work being done on the artificial heart and partial heart assist devices. These devices represent a prime example of incremental progress through years of research and development, and show how advanced technology from other fields can be applied to the solution of a medical problem.

A new heart assist device, now undergoing clinical testing, contains a miniature centrifugal pump incorporated into a catheter, which is inserted through an artery into the left ventricle. Driven by a small external motor connected to the pump by a mechanical shaft, the device can assist the heart by increasing blood flow markedly and so reducing heart work requirements.

Another development with a future is the use of the body's own parts to augment the function of the failing heart muscle. Research in progress is attempting to make skeletal muscle behave like heart muscle. The skeletal muscle will contract in response to electrical stimulation and can be wrapped around the heart or fashioned into an extra chamber to be used as an additional pump.

Another important milestone in 1991 was a report by a committee of the Institute of Medicine, Washington, D.C., which convened to evaluate the artificial heart program of the National Heart, Lung, and Blood Institute (NHLBI), Washington, D.C. The committee reaffirmed the need to continue developing a total artificial heart, recognized the importance of both total artificial hearts and heart-assist devices in treating a large patient population, and recommended that the NHLBI continue the funding for such efforts.

Dov Jaron (F) has been professor of biomedical engineering, professor of electrical and computer engineering, and director of the Biomedical Engineering and Science Institute at Drexel University in Philadelphia since 1980. In October he was named director of the Division of Biological and Critical Systems at the National Science Foundation (NSF), Washington, D.C. He will hold the post for two years. While at NSF, he will retain his position as a faculty member with Drexel and continue his research in cardiovascular dynamics.

Jaron's views are his own and not necessarily those of the National Science Foundation.

The specialties

- **Neural-network–fuzzy-logic nexus shows promise**
- **Quality-color costs decline for word processing and publishing**
- **Electromagnetic compatibility acquires a higher profile**
- **Engineering education up for major changes**

Neural networks are being coupled to fuzzy systems. . . new publishing and word-processing software can work in full color. . . methods of measuring electromagnetic compatibility (EMC) have improved. . . important changes in undergraduate engineering education are imminent. These comments on some of the more specialized branches of electrical engineering come from the IEEE Neural Networks Council, the IEEE Professional Communication Society, the IEEE Electromagnetic Compatibility Society, and the IEEE Education Society.

Robert J. Marks II, president of the IEEE Council on Neural Networks, calls the networks an extraordinary engineering tool, which is here to stay. They are already currently viable in a number of applications and useful, dedicated hardware is available. A promising area, he said, is the coupling of neural networks to fuzzy systems. "Layered perceptrons [feedforward artificial neural networks] can be taught fuzzy membership functions from raw data. Rules are thereby empirically learned."

A related discipline, Marks pointed out, is the genetic algorithm and associated evolutionary programming. The terminology, he said, "relates only loosely to the biological counterpart, not unlike reference to 'rabbit ears' or an 'electronic eye.' Genetic algorithms perform a highly parallel search of use in, say, the design and optimization of neural network architectures." But, Marks emphasized, as a technology, genetic algorithms and fuzzy nets are where neural networks were about a decade ago.

COLOR TAKEOVER. Prices have dropped and quality has surged in color scanners, color printers, and film recorders, according to David L. McKown, a member of the administrative committee of the IEEE Professional Communication Society. "Publishing (and even word-processing) software capable of working either full or 'spot' color is becoming readily available," he said. Today self-publishers can "afford to collect peripherals for scanning images in 256 colors, displaying them on monitors capable of 2000-by-2000 resolution or more, editing them using the unbelievably rich palette of colors of 24-bit systems, and printing them, unfortunately, on relatively low-resolution (100-dot-per-inch) printers."

But these tools encounter patches of ignorance, McKown emphasized. Few self-publishers (as compared with publishing houses) are trained in the intricacies, principles, and effects of color on an audience, so the color piece produced is too often "the design equivalent of ransom note typography." For another, what will the self-publisher do with the printed output? The original will have to be sent to a professional printer for color separation and printing, in which case "300-dpi resolution is usually unacceptably low."

The professional publisher faces many of the same problems. "The professional designer who used to specify colors on a tissue overlay and had a trusted printer implement them," McKown said, "now may use the software to change the colors in as many ways as are imaginable." But, he asked, "how accurately does the system monitor portray printed colors? How true to ink is the proof printer? How dependent will the designer become on the world of color created by electrons impinging on phosphorus and how estranged from the real world of pigments on paper?"

TAMING EMC. Electromagnetic compatibility has matured as a technology over the past several years, reported H. R. Hofmann, newly elected president of the IEEE Electromagnetic Compatibility Society. "Methods of performing EMC measurements have been enhanced with the aid of more sophisticated receivers including improved spectrum analyzers and antennas. The importance of accurate antenna factors has hit home, and techniques for measuring antenna factors have been widely disseminated."

Hofmann also said that the ability to make more repeatable measurements has spread with the publication of IEEE and ANSI standards on EMC measurement techniques and procedures. And, he maintained, new Federal Communications Commission rules on emissions have forced designers to deal with EMC early in the design process or else provide expensive, last-minute Band-Aid types of fixes.

William E. Cory of the administrative committee of the Society, said that, as an aid to the deliberations of the International Special Committee on Radio Interference, several countries reported on the incidence and causes of their electromagnetic interference (EMI). A first look, he said, showed that the number of occurrences reported is approximately proportional to the country's population.

In Japan and Norway, broadband noise from electric power distribution and motor-based appliances were said to be the major sources of EMI. In the United States, radio transmissions formed over two-thirds of the EMI sources.

ENGINEERING EDUCATION TRENDS. We are on the threshold of innovative changes in undergraduate engineering education, maintained Chalmers F. Sechrist Jr., president of the IEEE Education Society. One reason, he said, is the recommendations prepared during the 1980s by six entities: the IEEE Centennial Forum, the National Science Board, the American Society for Engineering Education (ASEE) Quality of Engineering Education Project, plus the Accreditation Board for Engineering and Technology National Congress on Engineering Education, the ASEE Task Force on a National Action Agenda for Engineering Education, and the National Science Foundation (NSF) Disciplinary Workshops on Undergraduate Education. Another reason is the increased NSF funding for innovative courses and curricula in undergraduate education in science, engineering, and mathematics.

Specific trends pointed out by Sechrist include:

- Engineering courses for nonengineers and, for engineering students, more interdisciplinary courses.
- More emphasis on engineering design, manufacturing, and concurrent engineering.
- Computer and design experiences in the freshman year.
- More emphasis on computer-aided instruction, education at a distance over communications links, and laboratory simulations.
- More use of engineering workstations.
- Improved student retention and advising.

Innovative programs incorporating those trends are taking shape at several universities, Sechrist reported, including Drexel, Cornell, Texas A&M, Maryland, Pennsylvania State, Texas Tech, and Vanderbilt, as well as at Rose-Hulman Institute of Technology and New Jersey Institute of Technology. ◆

Ronald K. Jurgen Senior Editor

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To probe further

PCs AND WORKSTATIONS. The IEEE Third Workshop on Workstation Operating Systems will be held April 23–24 at the Sheraton Royal Biscayne, Key Biscayne, Fla. Contact the IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

SOFTWARE. Two valuable reference books for brushing up on OS/2 are *Inside OS/2* by Gordon Letwin (Microsoft Press, Redmond, Wash., 1988) and *OS/2, Features, Functions and Applications* by Jeffrey I. Krantz, Ann M. Mitzell, and Robert L. Williams (John Wiley & Sons, New York, 1988). For greater detail on activities in engineering software for PCs and workstations, see the November 1991 issue of *IEEE Spectrum*, pp. 23–58 and p. 62. For Posix standards, see the December 1991 issue of *Spectrum*, pp. 36–39.

LARGE COMPUTERS. Most computer vendors have technical documents that describe their machines. A particularly good one is "The Connection Machine CM-5 Technical Summary," available from Thinking Machines Corp., 245 First St., Cambridge, Mass. 02142; 617-234-1000. *Computer*, published monthly by the IEEE Computer Society, is a source of general technical news as well as in-depth articles.

TELECOMMUNICATIONS. A succinct background paper on the major issues of WARC-92—particularly those facing the U.S. government—is *The 1992 World Administrative Radio Conference: Issues for U.S. International Spectrum Policy*, prepared by the Office of Technology Assessment, U.S. Government Printing Office, November 1991. The 134-page document, 052-003-01265-1, is available for US $6.50 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

The technology of and developments in personal communications services are covered by the biweekly newsletter *Telecommunications Reports Wireless News*, available from BRP Publications Inc., 1333 H St., N.W. (11th floor west), Washington, D.C. 20005; 202-842-3006. The annual subscription for 25 issues is $395.

DATA COMMUNICATIONS. The IEEE International Workshop on Advanced Communications and Applications for High Speed Networks will take place March 16–19 at the Penta Hotel, Munich. Contact Alfred C. Weaver, Department of Computer Science, Thornton Hall, University of Virginia, Charlottesville, Va. 22901; 804-982-2201.

Interop 92—the Seventh Interoperability Conference and Exhibition—will be held May 18–22 at the Washington, D.C., Convention Center. Contact Interop Inc., 480 San Antonio Rd., Suite 100, Mountain View, Calif. 94040-1219; 415-941-3399, ext. 2502.

SOLID STATE. *The Microprocessor Report*, as of this month a triweekly newsletter, contains reviews and analyses of microprocessors, microcontrollers, and related chips. It is available for $445 per year from MicroDesign Resources Inc., 874 Gravenstein Highway South, Suite 14, Sebastopol, Calif. 95472; 707-823-4004.

This year's International Solid-State Circuits Conference will be held Feb. 19–21 at the San Francisco Hilton Hotel. Contact Diane Suiters, Courtesy Associates, 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-4255.

For the Custom IC Conference to be held at the Westin Hotel in Boston May 3–6, contact Roberta Kaspar, 1597 Ridge Rd. West, Suite 101C, Rochester, N.Y. 14615; 716-865-7164.

The VLSI Technology Symposium follows June 2–4 at the Westin Hotel, Seattle, Wash. Contact Dru Montgomery, Courtesy Associates (see address above).

TEST AND MEASUREMENT. Details of the IEEE Instrumentation and Measurement Technology Conference scheduled for May 12–14 at the Meadowlands Hilton Hotel, Secaucus, N.J., may be obtained from Robert Myers, 3685 Motor Ave., Suite 240, Los Angeles, Calif. 90034; 213-287-1463.

INDUSTRIAL ELECTRONICS. Kobe, Japan, played host to IECON '91, the 1991 International Conference on Industrial Electronics, Control and Instrumentation, from Oct. 28 through Nov. 1. Order the conference proceedings, IEEE Publication 91CH2976-9, from the IEEE Service Center.

About a $35 billion investment in industrial automation in the United States in 1989 is itemized in the *Industrial Automation Investment Profile*, the first report of its kind. Contact William C. Rolland, executive director, Automation Forum, National Electrical Manufacturers Association, 2101 L St., N.W., Washington, D.C. 20037; 202-457-1975, or for direct order, 301-604-8002.

POWER AND ENERGY. *The Electricity Journal* is a monthly publication with news and in-depth reports on critical issues in the utility industry. The journal's offices are at 1932 First Ave., Suite 809, Seattle, Wash. 98101; 202-448-4078. *IEEE Power Engineering Review*, published by the Power Engineering Society, covers similar ground and contains Society news as well.

CONSUMER ELECTRONICS. The latest consumer electronic products are exhibited by manufacturers twice a year at the International Winter and Summer Consumer Electronics Shows: this year's summer show is in Chicago, May 28–31. Contact the Consumer Electronics Group, Electronic Industries Association, 2001 Pennsylvania Ave., N.W., Washington, D.C. 20006-1813; 202-457-8700.

The *IEEE Transactions on Consumer Electronics* contains articles on the design and manufacture of consumer electronic products, components, and related activities.

TRANSPORTATION. *In Pursuit of Speed: New Options for Intercity Passenger Transport* is available for $22. Call the Transportation Research Board, National Research Council, 2101 Constitution Ave., N.W., Washington, D.C. 20418, at 202-334-3214. The Office of Technology Assessment's *Moving Ahead: 1991 Surface Transportation Legislation* is available for $3.50 from the U.S. Government Printing Office, Washington, D.C. 20402-9325; 202-783-3238. Ask for stock number 052-003-01245-6.

AEROSPACE AND MILITARY. *The Start Treaty and Beyond*, October 1991, is a report on arms control. One copy is available at no charge from the U.S. Congressional Budget Office, Second and D Streets, S.W., Washington, D.C. 20515; 202-226-2809. *Tactical Technology*, a biweekly newsletter costing $395 per year, is published by Phillips Publishing Inc., 7811 Montrose Rd., Potomac, Md. 20854; 301-340-2100.

MEDICAL ELECTRONICS. *The Artificial Heart: Prototypes, Policies, and Patients* is available for $24.95 (prepaid) plus $3 shipping from the National Academy Press, 2101 Constitution Ave., N.W., Washington, DC. 20418; 202-334-3313 or 1-800-624-6242.

For information on IEEE publications, contact the IEEE Service Center, 445 Hoes Lane, Piscataway, N.J. 08855-1331; 908-981-1393.

ACKNOWLEDGMENTS

This issue would not have been possible without the help of the many expert technical reviewers we call upon to critique the material planned for the issue before it is released for publication.

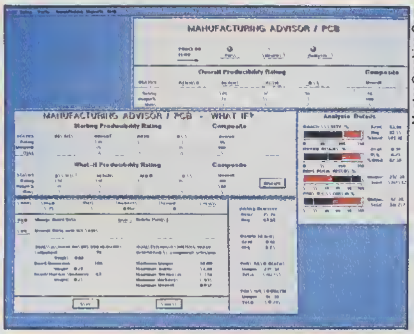
The pictures of the experts that appear with each major article in this issue were drawn by Barry Ross, Northampton, Mass.

EEs' tools & toys

Designing circuit boards for manufacturability

Considering the downstream effects on manufacturing of early design decisions is a practice more honored in the breach than the observance. But one of a new generation of design assistance tools supporting concurrent engineering, Manufacturing Advisor/PCB, helps designers of printed-circuit board assemblies do just that. The software from Mentor Graphics Corp. gives designers better control over product costs, quality, and delivery schedules.

The software can identify parts-related manufacturing problems in board assemblies—both by providing a manufacturability score, and by allowing pc board designers to interactively perform WHAT IF analyses to test the effect of design alternatives.



Mentor Graphics Corp.

Mentor Graphics' Manufacturing Advisor/PCB analyzes printed-circuit board designs at an early stage for manufacturability. The overall analysis sheet in the background includes initial manufacturing ratings in four areas. The red text indicates a critical problem with component placement density.

Throughout the circuit-design process, Manufacturing Advisor/PCB can analyze an assembly on the basis of the parts selected so far. Even before schematic capture is begun, design engineers can get a preliminary analysis by entering a parts list. Then, as components are added to a design, Manufacturing Advisor monitors how much placement area has been used. If the maximum area is exceeded, the software identifies components that could be mounted in an alternative configuration with a smaller footprint.

Manufacturing Advisor/PCB also assesses whether the components for a given design can be automatically inserted. As the design is refined through schematic capture and board layout, the software continues to identify parts associated with unusual labor requirements, special manufacturing processes, high risk of manufacturing rework, and failure to comply with standards.

Texas Instruments Inc., whose Information Technology Group did the development, has used the technology internally for some four years, turning out more than 3000 circuit-board designs, noted Mentor Graphics. TI recently engineered the technology for the commercial marketplace. The company also plans to develop enhancements.

Manufacturing Advisor/PCB depends for parts and manufacturability information on a components library of more than 800 package styles. They represent tens of thousands of parts from manufacturers worldwide.

Price of Manufacturing Advisor/PCB is US $16 900 for Hewlett-Packard Apollo platforms. Versions for Sun Microsystems and HP Apollo Series 700 workstations are due before the first quarter of the year is over. The parts library is a $1500 option.

Manufacturing Advisor/PCB is also an op-

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PC version: MS-DOS 2.1 or later, only 512Kb RAM and one 3.5" or 5.25" disk drive. Suggested retail price is $250.

ROM-card version: Hewlett-Packard 95LX Palmtop computer. Suggested retail price: $289.

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tion for Mentor Graphics' Idea Station and Board Station application-specific IC and board design software. *Contact: Mentor Graphics Gateway Marketing Center, Box 5050, Wilsonville, Ore. 97070-7777; 800-547-3000 or 503-685-7000; fax, 501-685-1202; or* **circle 101.**

SOFTWARE

Multimedia portability

The problems of portability and programmability in multimedia applications have been addressed by the second version of cT, with which the user can write programs incorporating pictures, sound, and video sequences that are portable among MS-DOS and Macintosh personal computers and Unix-based workstations.

Version 2 of cT is a programming language tailored for education and research, according to David Anderson, system programmer at Carnegie Mellon University's Center for Design of Educational Computing (CDEC) in Pittsburgh, where Version 2 was developed. In its first version, it was used to create instructional materials in psychology, veterinary medicine, physics, and philosophy, and has served as a general programming tool providing a graphical front-end for scientific applications.

Version 2 adds support for foreign languages, and manipulation of text rich in styles, fonts, and embedded images. Features of the original language—complex graphics from standard sources such as the Macintosh Clipboard or a PCX file on a PC, pull-down menus, and mouse interactions—have been retained. It also offers automatic rescaling so text and graphics remain synchronized in windows of various sizes. *Contact: John Kornet, Falcon Software, Box 200, Wentworth, N.H. 03282; 603-764-5788; fax, 603-764-9051; or* **circle 102.**

Viral trap

Need help combatting computer viruses like Disk Killer, Swedish Disaster, and Black Monday? These and other viruses were stopped by hardware-based Virus Trap, which maintains a clean DOS environment through a hard-disk operation by preventing viruses from infecting the system during startup. It does this by barring access to certain areas of the hard disk and recognizing corrupted files.

In the startup procedure for an IBM Corp. or compatible personal computer, software-based virus protection products must wait to go into operation until reset/power-up. During this period the system is not protected against viruses and can be infected. Virus Trap, however, secures the DOS environment, hard disk, boot sector, system files, and partition table, inoculating them against infection. It also informs the user if a hidden file is infected, and recommends its reinstallation. It does not replace scanning software packages, but protects the period during startup they cannot cover.

Virus Trap can also detect DIR-2, a new class of virus that inserts a redirection to itself in the directory entries, leaves a terminate-and-stay-resident (TSR) redirecting call to its storage location, and filters calls for directory contents.

The guts of the credit-card–size, 5-by-7.6-by-1.25-cm Virus Trap are two proprietary chips developed by J.A.S. Technology of the Americas. The card is installed in line in the communication cable between the hard-disk controller card and the hard disk of IBM and compatible PCs. It does not reduce operating speed or take up a bus slot, and it is user transparent. Virus Trap sells for US $395. *Contact: Anne Stewart, J.A.S. Technology of the Americas, 96 Raider Dr., Warrenton, Va. 22186; 703-349-0696; or* **circle 103.**

COORDINATOR: Dana Norvila
CONSULTANT: Paul A.T. Wolfgang, Boeing Helicopters

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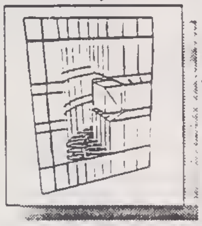

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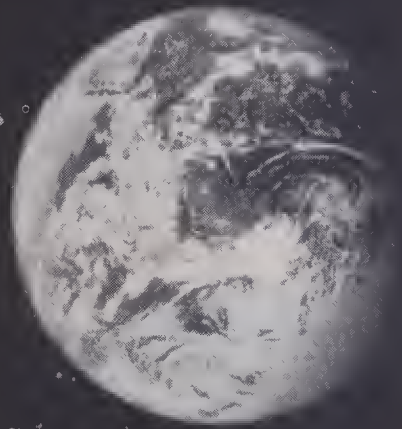

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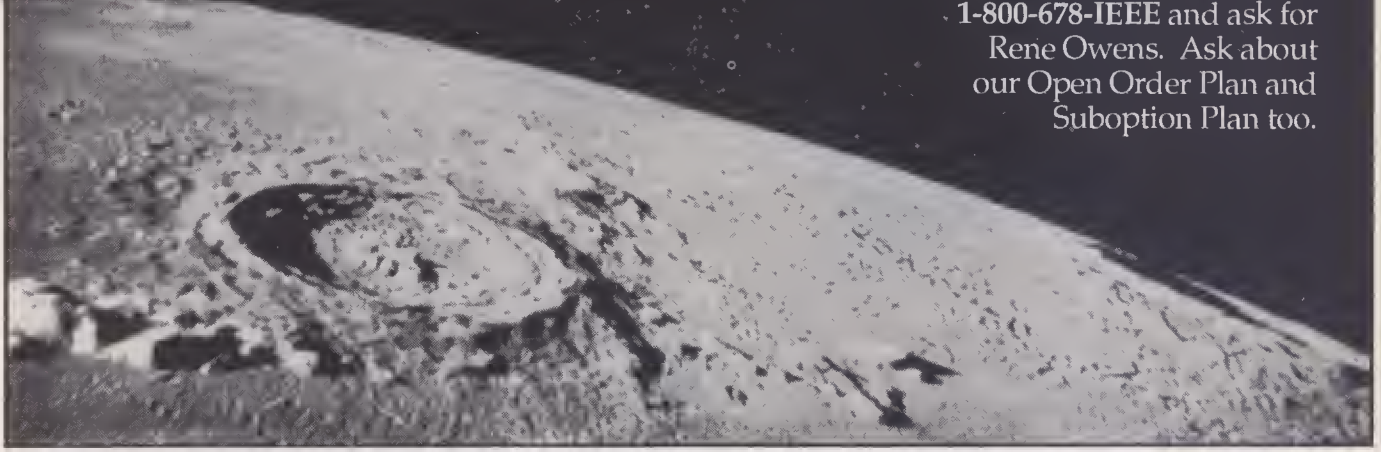

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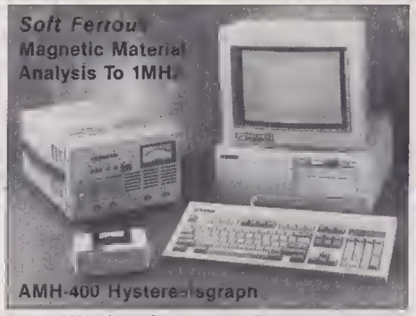

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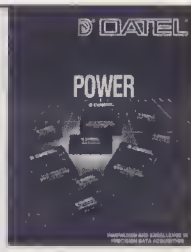

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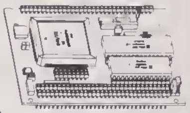

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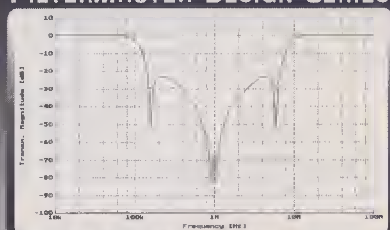

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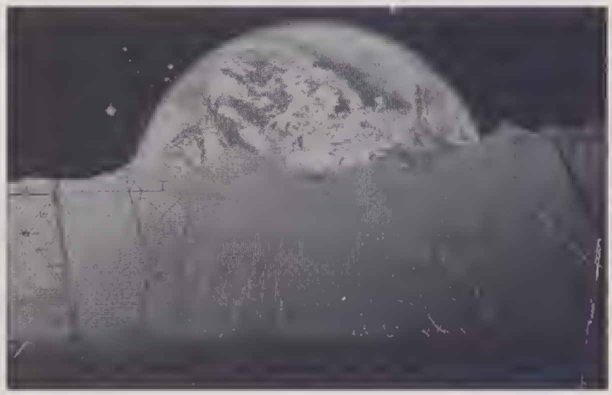

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tories, Data Storage Systems laboratories as well as Optical and Digital Processing laboratories. The successful candidate should have an earned Ph.D. in Electrical/Computer Engineering or related fields, an internationally recognized research stature and the experience and abilities to lead the teaching and research excellence of the department. Nominations/Applications, along with a vita and the names, addresses and phone numbers of three references should be sent to: Professor B.V.K. Vijaya Kumar, Chairman, ECE Department Head Search Committee, Department of Electrical and Computer Engineering, Carnegie Mellon University, Pittsburgh, PA 15213-3890. The search committee will consider all applications and nominations received up to February 1, 1992. Carnegie Mellon University is an affirmative-action, equal opportunity employer.

The Department of Electrical Engineering and Computer Engineering invites applications for several anticipated tenure-track faculty positions. Applicants at all ranks will be considered. Starting dates are negotiable with preference given for fall 1992. Primary needs are for specialization in the areas of communications, signal processing, controls, computer networks, distributed computing, data communications, microelectronics and VLSI design. Responsibilities include teaching, research and outreach. Salary and rank are commensurate with qualifications and experience. Requirements include a doctorate degree with a demonstrated potential for success in research and a commitment to teaching. Applicants should send a resume with a statement of teaching, research, and outreach interests, as well as a list of at least three (3) references to: Chairman, Faculty Search Committee, Department of Electrical Engineering and Computer Engineering, Iowa State University, Ames, Iowa 50011. Iowa State University is an Equal Opportunity/Affirmative Action Employer.

The Johns Hopkins University, Department of Electrical and Computer Engineering, invites applications for tenure-track faculty positions at the assistant or associate professor level in the areas of computer engineering; solid state and quantum electronics; and signal and image processing. Candidates for associate professor appointments are expected to have significant research records. Candidates for assistant professor appointments are expected to show strong research potential. Applicants should send resumes, including names of at least three references, to Search Committee, Department of Electrical and Computer Engineering, The Johns Hopkins University, Baltimore MD 21218-2868. The Johns Hopkins University is an equal opportunity/affirmative action employer.

The Department of Electrical Engineering of Arizona State University is seeking a faculty member who will play a leading role in the future development of the Nuclear Engineering Science Program at Arizona State University. The successful applicant must have an earned doctoral degree with considerable research experience in a combination of Nuclear and Electrical Engineering. The successful applicant is expected to excel in teaching, at both the undergraduate and graduate levels, and to support activities in either the Electric Power Research Laboratory and/or the Center for Systems Science and Engineering. Preferred areas of specialization include reactor controls, computational reactor analysis, reactor safety, materials damage and instrumentation. Depending upon the background and experience of the successful applicant, there is potential for contract involvement with nearby Palo Verde, the largest Nuclear Generating Station in the world. Academic rank will be commensurate with the candidate's background and experience. Please send vita to Dr. David K. Ferry, Chairman, Department of Electrical Engineering, Arizona State University, Tempe, AZ 85287-5706, Attention: Faculty Search Committee. The next deadline is February 6, 1992, or the 6th of each month until the position is filled. Arizona State University is an equal opportunity, affirmative action employer. Women and minorities are encouraged to apply.

(Continued on p. 74)

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Areté Associates is a nationally recognized R&D company specializing in remote ocean sensing for the Department of Defense. We are experts in experiment design, oceanographic data analysis, theoretical modeling and numerical simulation of physical processes, and performance assessment of prototype systems. We offer a unique small company atmosphere that encourages employee participation and allows the freedom to explore the challenges of the future in technology and the physical sciences. We currently have the following opportunities:

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Will perform significant research in modeling and data analysis of remote oceanographic and atmospheric measurements. Requires an advanced degree in physics, mathematics, or engineering and related work experience. Must have knowledge of radar and passive IR measurements as well as magnetic and other low frequency electro magnetic sensors.

Scientific Programmer/Analyst

Will perform assessment analysis of advanced sensor systems, implementation of signal processing algorithms, data analysis, and mathematical & physical modeling. Requires a degree in mathematics, engineering, or physical science and a minimum of 2 years scientific programming experience. Advanced degree preferred. Must be technically oriented with strong computer skills.

Real-Time Software Engineer

Requires a Bachelor's or Master's degree in engineering or physical science. Must have development experience with state-of-the-art digital signal processing & display systems; OS architectures & device drivers (SunOS, VxWorks, MS-DOS); large software projects; embedded processors, real-time kernels; C, Ada & assembly; and Windows.

Areté rewards its employees with an excellent compensation and benefits package which includes a liberal leave policy, paid medical/dental/vision/life insurance, pension plans, and advancement opportunities. An active DoD security clearance is a definite plus. For consideration, please send your resumé to: Areté Associates, Human Resources Dept. 3E, P.O. Box 6024, Sherman Oaks, CA 91413. Drug test, U.S. Citizenship and Security Investigation are required to meet position eligibility. EOE

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University of Rhode Island

DEAN

College of Engineering University of Rhode Island

The University of Rhode Island invites nominations and applications for the position of Dean of the College of Engineering. The College consists of six departments (Chemical, Civil and Environmental, Electrical, Industrial and Manufacturing, Mechanical and Applied Mechanics, and Ocean); 950 undergraduate and 270 graduate students; 80 tenure-track faculty; and over $3M in extramural awards. Degrees conferred include BS, MS and PhD.

Required qualifications for the position are:

- Earned doctorate in Engineering and credentials for tenured, full professor appointment in an engineering department
- Record of obtaining research support from federal and corporate sponsors
- Demonstrated leadership and support for faculty research activities
- Evidence of strong advocate's role for engineering in and outside the University
- Significant prior administrative experience in an academic setting
- Effective interpersonal communication and verbal presentation skills, and
- Demonstrated ability to build strong and supportive relationships with industry, government leaders, and alumni.

Duties and responsibilities:

- As College's chief academic officer, provide quality leadership and vision for its research, education and service missions
- Ensure excellence in all College activities and programs
- Develop strong relationships with companies, government, and alumni
- Effectively represent College both inside and outside University
- Enhance and facilitate research and funded activities of faculty and staff, and
- Develop and maintain good working relationships with faculty, staff, administrators, and students.

The University is a land grant and sea grant institution, located between New York and Boston, six miles from the Atlantic Ocean, and offers a stimulating research and educational environment. In 1990-91 total extramural funding exceeded $33M with internationally recognized programs in engineering, oceanography, and environmental sciences. Total enrollment exceeds 16,500.

The preferred starting date is July 1, 1992. Candidates should supply a current curriculum vita and letter of interest detailing qualifications and experiences. The committee will begin reviewing applications on January 15, 1992 and continue until the search is completed. Applications from minority and women candidates are especially encouraged. Salary commensurate with credentials.

Nominations and applications should be addressed to:

URI

Dr. Ronald D. Hedlund, Chair
Search Committee for Engineering Dean
Position #081026
The University of Rhode Island
Post Office Box G, Kingston, RI 02881

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CHAIRPERSON

DEPARTMENT OF ELECTRICAL ENGINEERING
University of Maryland at College Park

Applications and nominations are invited for the position of Professor and Chairperson of the Department of Electrical Engineering. Candidates should have an earned doctorate in electrical engineering or a closely related field, strong leadership ability, a proven research record, and a commitment to electrical engineering education.

The Electrical Engineering Department consists of 60 faculty at the College Park campus and 8 faculty at the neighboring Baltimore County campus. The faculty include 28 Fellows of the IEEE and APS, and 9 PYI's. Annual degree production overall is about 250 BS, 100 MS, and 30 PhD's. Last year, the sponsored research exceeded \$13M, in areas such as circuits, communications, computers, controls, electrophysics, and microelectronics.

Applications and nominations should be sent to:

Dr. Patrck F. Cunniff
Chair, Search Committee
Department of Mechanical Engineering
College Park, MD 20742

Applications received prior to Feb. 21, 1992 will receive first consideration.

THE UNIVERSITY OF MARYLAND IS AN EQUAL OPPORTUNITY AFFIRMATIVE ACTION EMPLOYER.

UNIVERSITY OF MASSACHUSETTS AT AMHERST
DEAN OF THE COLLEGE OF ENGINEERING

The University of Massachusetts invites applications and nominations for the position of Dean of the College of Engineering. The College of Engineering comprises 1,600 undergraduate and 600 graduate students in the Departments of Chemical, Civil, Electrical and Computer, Industrial, and Mechanical Engineering, an off-campus M.S. in Engineering Management, and separately accredited M.S. programs in Environmental and Manufacturing Engineering. The 103 faculty are responsible for \$10,000,000 in sponsored research. The Engineering College recently opened a new research building and is completing construction of a new student center.

The Dean of Engineering reports to the Provost. The successful candidate must possess:

- An earned doctorate in engineering or science-related field
- A distinguished record as a scholar showing commitment to research and teaching
- Demonstrated administrative ability
- Effective communication and interpersonal skills
- Success in obtaining research support from government and industry
- Ability and interest in fund-raising
- Commitment to increasing diversity among students, faculty, and staff

Salary commensurate with experience and qualifications. The position is available September, 1992; the Search Committee will begin reviewing applications in February, 1992 and will accept applications until the position is filled. Applicants should send a vitae and the names, addresses and telephone numbers of four references to:

Professor Richard J. Giglio, Chair
Engineering Dean Search Committee
c/o Provost's Office, 362 Whitmore
The University of Massachusetts
Amherst, Massachusetts 01003

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PROFESSOR AND HEAD ELECTRICAL AND COMPUTER ENGINEERING MISSISSIPPI STATE UNIVERSITY

Nominations and applications are invited for the position of Professor and Head of Electrical and Computer Engineering at Mississippi State University. The Department of Electrical and Computer Engineering offers ABET accredited undergraduate programs and graduate degrees through the doctorate in both Electrical Engineering and Computer Engineering. It has 26 faculty, 12 professional and administrative support staff members, an undergraduate enrollment of approximately 560 in electrical engineering and 170 in computer engineering, and a graduate enrollment of approximately 130 students. The department has an excellent record of scholarly achievement and ranks in the top 70 in externally funded research expenditures among Electrical Engineering Departments in the U.S., with expenditures from externally funded research being approximately equal to expenditures for education. It has a major role in the MSU/NSF Engineering Research Center and owns and operates the High Voltage Laboratory, a unique facility for an educational institution in the nation.

Applicants must hold an earned doctorate. They should possess a vision for the future directions of Electrical and Computer Engineering and have leadership and managerial skills to promote and implement that vision. A scholarly record of publications in archival literature, conference presentations, and externally funded research experience is expected. The new Head should have teaching experience at both the undergraduate and graduate levels and must qualify for the rank of professor.

Mississippi State University is a comprehensive land grant institution and is among the top 100 research-funded institutions in the United States as defined by the National Science Foundation. The College of Engineering is one of nine colleges/schools in the University. The University has 758 faculty members and over 13,700 on-campus students.

The Department of Electrical and Computer Engineering is one of eight academic departments in the College of Engineering. The College has 120 faculty, 2243 undergraduate and 306 graduate students, and funded research expenditures which exceeded $12 million for FY91. A new Mississippi Research and Technology Park, located adjacent to the campus, is contributing greatly to the research programs of the college.

Initial screening of applications will begin February 15, 1992, and will continue until the position is filled. Send nominations or applications and resumes, including names, addresses, and telephone numbers of at least three references to:

Dr. John C. McWhorter III, ECE Search Committee
Mississippi State University, P.O. Drawer A
Mississippi State, MS 39762

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SENIOR DEVELOPMENT ENGINEER

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This position requires a degree in Electrical Engineering with 5-7 years experience in physiology **OR** a degree in physiology with 5-7 years experience in electrical engineering. Familiarity with the clinical application of patient monitors required; background in process and analysis of physiological signals desirable.

If you meet these requirements, please send resume in confidence to: **Headquarters Personnel Manager, CRITIKON, INC.,P.O. Box 31800, Dept. SDE, Tampa, FL 33631.** Equal Opportunity Employer M/F/H/V

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Research Officer (Ottawa, Ontario)

The Photonic Systems project of the Autonomous Systems Laboratory of NRC's Institute for Information Technology is performing R&D, in collaboration with industrial partners, on optical computing with particular emphasis on machine vision applications. The successful candidate will develop new algorithms/architectures for pattern recognition and optical fast search of massive data-bases. Strong interface with on-going experiments is expected. Ph.D. in Electrical Engineering or Physics. Five-year minimum research experience subsequent to Ph.D. Extensive experience in optical processing/computing architectures and implementations. In-depth knowledge of optical processing/computing architectures or signal processing and implementations. Expertise in parallel processing, neural networks and database management algorithms would be a definite asset. Demonstrated ability in initiating, performing and supervising research projects. Ability to function well either individually or as a team member or leader. Demonstrated research leadership capabilities.

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To perform analog and digital circuit design, SW development and test system integration. Requires BSEE and 3+ years ATE experience in the design/development of computer-based automatic production test equipment. **Respond to Dept. IEEE/ATE.**

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Utilizing Sun SPARC workstations, will layout CMOS analog/digital circuits with standard cell and fully customized methodologies. Requires 2+ years layout experience and working knowledge of UNIX. **Respond to Dept. IEEE/ICDE.**

PROCESS ENGINEER

Will handle machine design projects utilizing electro-pneumatic mechanisms/processes involving YAG laser welding. Requires BSME/EE with 5 years experience in CNC machine control, diagnostics, mechanical fixture design and repair of digital/analog circuits. **Respond to Dept. IEEE/PE.**

SR. PROCESS ENGINEER

Will develop/implement new processes, equipment, components and manufacturing methods to support hybrid test and manufacturing. Emphasis will be on improving manufacturing yields, designing SPC systems and conducting hybrid material R&D. Requires BSEE/ME; 5 years hybrid experience preferred. **Respond to Dept. IEEE/SPE.**

SR. ANALOG ENGINEER

Duties involve switching power supplies/hybrid power circuits for implantable medical devices. Requires BS/MSEE or PhD and 5+ years experience in analog circuit design, prototype, test and debug. **Respond to Dept. IEEE/APE.**

SR. COMPONENT RELIABILITY ENGINEER

Requires BSEE with 5 years experience in reliability engineering, failure analysis techniques and rate predictions. Knowledge of IC and hybrid design/evaluation/qualification techniques and CMOS is essential. **Respond to Dept. IEEE/CRE.**

SR. ANALOG ELECTRONICS DESIGN ENGINEER

Duties include designing low power CMOS op amps and switched capacitor circuits and overseeing layout. Will also perform some system design, integration and scheduling. Requires BS/MS in Electronics, 10+ years analog design experience and 5+ years IC design experience. Thorough knowledge of SPICE and FET models a must. **Respond to Dept. IEEE/AEDE.**

SR. ELECTRONIC PRODUCT ENGINEER

BSEE and 3-5 years experience in analog/digital design, CMOS/TTL devices and microprocessor-based systems essential. Ideal candidate will have knowledge of hybrid micro-electronics involved in the manufacture of high-reliability electronic devices. **Respond to Dept. IEEE/EPE.**

SOFTWARE ENGINEER

Utilizing Assembly and C languages, will design/develop system and application SW for real-time embedded microprocessor-based pacemaker support products. Requires BSEE/CE or equivalent and 3+ years experience in embedded microprocessor and system-level SW design/development. **Respond to Dept. IEEE/SE.**

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1992 IEEE guide for authors

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If you require general guidance in IEEE style, send for *Information for IEEE Transactions and Journal Authors,* available at the above address. Specific authors' information may also be found in many of the journals themselves, usually on the back or inside back cover. All guides are free. They must be requested by their correct titles to avoid confusion.

In the listings below, frequency of publication is noted in parentheses.

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IEEE Spectrum has the largest international circulation among magazines in the electrical/electronics field; it affords the primary link between the IEEE and all its members. *Spectrum*'s objectives are to provide interesting and useful information on a broad range of technical and career-oriented topics and to increase the awareness among readers of fields outside their immediate specialties. The *Spectrum* staff works closely with authors to help them revise their manuscripts, drastically when necessary, to gain high readability and utility to the reader.

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For information on manuscript submission: IEEE Potentials, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331

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Publishes comprehensive, in-depth review, tutorial, and survey material written for readers who are not specialists in the subjects being treated. It specializes in material of broad significance and long-range interest in all technical fields within the scope of the IEEE, including all aspects of electrical and computer engineering and science. From time to time, papers emphasizing managerial, historical, economic, and ethical aspects of technology are published. Authored by recognized authorities, papers include extensive introductions written at a level suitable for the nonspecialist, with numerous references for those wishing to probe further. A number of issues a year are devoted to a single subject of special importance. (12)
Executive Editor, Proceedings of the IEEE, 345 E. 47th St., New York, N.Y. 10017 212-705-7557

IEEE TRANSACTIONS, JOURNALS, AND MAGAZINES

These publications of IEEE Societies provide the means by which the member keeps abreast of the advances in a specific field of specialization. Their mission is to record and disseminate new scientific and technical information for both present and future members of the profession.

Aerospace and Electronic Systems, IEEE Trans.
Equipment, procedures, and techniques applicable to the organization, installation, and operation of functional systems designed to meet high-performance requirements of earth and space systems. (4)
Jack R. Harris, 20400 Highland Hall Dr., Gaithersburg, Md. 20879 301-251-4810

Aerospace and Electronic Systems Magazine
Articles dealing with aspects of earth and space systems, radar, navigation, guidance and control, and communication data handling as well as systems for their simulation and test. Intended to keep engineers current in development, operation, and test of civil and military electronic systems. (12)
H. Warren Cooper, 7211 Windsor Lane, Hyattsville, Md. 20782 301-927-7681

Annals of the History of Computing
Chronicles of vital contributions and their impact on society. Departments: Happenings; Biographies; Anecdotes; Self-Study Q&A; Reviews; and Comments, Queries, and Debate.
J.A.N. Lee, V.A. Tech. Dept. of ITT, 133 McBride Hall, Blacksburg, Va. 24061

Antennas and Propagation, IEEE Trans.
Experimental and theoretical advances in electromagnetic theory and in the radiation, propagation, scattering and diffraction of electromagnetic waves, and the devices, media and fields of application pertinent thereto such as antennas, plasmas, and radio astronomy systems. (12)
Robert E. McIntosh, Dept. of ECE, University of Massachusetts, Amherst, Mass. 01003 413-545-0709

Antennas and Propagation Magazine
Covers all areas relating to antenna theory, design and practice; propagation, both theory and effects; and a broad range of general interest topics including basic electromagnetics, computational and numerical techniques, personal computers for EEs, scattering and diffraction, radar and radar cross sections. (6)
W. Ross Stone, IRT Corp., 1446 Vista Claridad, La Jolla, Calif. 92037 619-597-8727

Applied Superconductivity, IEEE Trans.
Contains articles on the applications of superconductivity and relevant technology. Electronic applications include analog and digital circuits employing thin films and active devices such as Josephson junctions. Power applications include magnet design as well as motors, generators, and power transmission. (4)
Theodore Van Duzer, Dept. of EECS, University of California, Berkeley, Calif. 94720 415-642-3306

Automatic Control, IEEE Trans.
The theory, design, and application of control systems: real-time control, optimal control, adaptive and stochastic control, estimation and identification, linear systems, system modeling, and applications of physical, economic and social systems. (12)
N.H. McClamroch, Department of Aerospace Engineering, University of Michigan, Ann Arbor, Mich. 48109 313-763-9304

Biomedical Engineering, IEEE Trans.
Broad coverage of concepts and methods of the physical and engineering sciences applied in biology and medicine, ranging from formalized mathematical theory through experimental science and technological development to practical clinical applications. (12)
Dr. Michael R. Neuman, Obstetrics & Gynecology, Cleveland Metro General Hospital, 3395 Scranton Rd., Cleveland, Ohio 44109 216-459-5095

Broadcasting, IEEE Trans.
Broadcast technology, including the production, distribution, transmission, and propagation aspects of

broadcasting. (4)
Phil Rubin, Rubin, Bednarek & Associates, 1350 Connecticut Ave., Suite 610, Washington, D.C. 20036 202-296-9380

Circuits and Devices Magazine
Provides in-depth assessments of emerging technologies and their continued impact on the man-machine interface. Included are papers and tutorials on VLSI; manufacturing technology; semiconductor processes; quantum electronics; digital and analog circuits; components and packaging. Also, book reviews, news and notes, conferences, workshops, seminars, and lectures. (6)
Ronald W. Waynant, Food and Drug Administration, Center for Devices and Radiological Health (CDRD), Electro-Optics Branch, HF2-134, 1901 Chapman Rd., Rockville, Md. 20857 301-443-2965

Circuits and Systems, Part I: Fundamental Theory and Applications; IEEE Trans.
Widely recognized forum for new results in electronic circuits and systems; system theory; discrete, IC, and VLSI circuit design; nonlinear circuits and systems; multidimensional circuits and systems; theory of analog and discrete-time filtering; graph theory; and large-scale systems and power networks. (12)

Circuits and Systems, Part II: Analog and Digital Signal Processing; IEEE Trans.
Encompasses most aspects of analog and digital signal processing, including active, passive, switched-capacitor, and digital filters; nonlinear filters and signal-processing operators; new hardware structures and software algorithms for signal processing; video and image processing; and signal processing in higher dimensions. (12)
Wai-Kai Chen, Dept. of Electrical Engineering, University of Illinois at Chicago, Chicago, Ill. 60680 312-996-2462

Circuits and Systems for Video Technology, IEEE Trans.
Video A/D and D/A, display technology, image analysis and processing, video signal characterization and representation, video compression techniques and signal processing, multidimensional filters and transforms, analog video signal processing, neural networks for video applications, nonlinear video signal processing, video storage and retrieval, computer vision, packet video, high-speed real-time circuits, VLSI architecture and implementation for video technology, multiprocessor systems—hardware and software—video systems architecture, video quality assessment, and other video-technology–related topics. (4)
Ming Liou, Bellcore, 3X-303, 331 Newman Springs Rd., Red Bank, N.J. 07701 201-758-2949

Communications, IEEE Trans.
Telephone, telegraphy, facsimile, and point-to-point television, by electromagnetic propagation, including radio; wire; aerial, underground, coaxial, and submarine cables; waveguides, communication satellites, and lasers; in marine, aeronautical, space and fixed station services; repeaters, radio relaying, signal storage, and regeneration; telecommunication error detection and correction; multiplexing and carrier techniques; communication switching systems; data communications; and communication theory. In addition to the above, this Transactions contains papers pertaining to analog and digital signal processing and modulation, audio and video encoding techniques, the theory and design of transmitters, receivers, and repeaters for communications via optical and sonic media, the design and analysis of computer communication systems, and the development of communication software. (12)
James F. Kurose, Dept. of Computer & Information Science, University of Massachusetts, Amherst, Mass. 01003

Communications Magazine
All areas of communications: conferences, short courses, standards, governmental regulations and legislation, book reviews, and special feature technical articles; Society news, including administration and elections. (12)
Ray R. Laane, Bellcore, 445 South St., Room 2F-287, Morristown, N.J. 07960 201-829-4067.

Communications, Selected Areas in; IEEE J.
All telecommunications, including telephone, telegraphy, facsimile, and point-to-point television, by electromagnetic propagation, including radio; wire; aerial, underground, coaxial, and submarine cables; waveguides, communication satellites, and lasers; in marine, aeronautical, space, and fixed station services; repeaters, radio relaying, signal storage, and regeneration; telecommunication error detection and correction; multiplexing and carrier techniques; communication switching systems; data communications; and communication theory. (9)
William H. Tranter, Dept. of EE, University of Missouri, Rolla, Mo. 65401 314-341-4514

Components, Hybrids, and Manufacturing Technology, IEEE Trans.
Component parts, hybrid microelectronics, materials, packaging techniques, and manufacturing technology. (6)
Paul G. Slade, Westinghouse R&D, 1310 Beulah Rd., Pittsburgh, Pa. 15235-5098 412-256-1010

Computer-Aided Design of Integrated Circuits and Systems, IEEE Trans.
Methods, algorithms, and man-machine interfaces for physical and logical design, including: planning, synthesis, partitioning, modeling, simulation, layout, verification, testing, and documentation of integrated-circuit and systems designs of all complexities. Practical applications of aids resulting in producible analog, digital, optical, or microwave integrated circuits are emphasized. (12)
Alfred E. Dunlop, AT&T Bell Labs, Room 3D-484, 600 Mountain Ave., Murray Hill, N.J. 07974 908-582-6579

Computer Applications in Power Magazine
Magazine devoted to computer applications to the design, operation, and control of power systems. Includes articles on transient network analysis, circuit evaluation, steady-state analysis, cable management systems, economics, and contingency analysis. (4)
William R. Brownlee, 780 Montgomery Dr., Birmingham, Ala. 35213 205-871-5662

Computer Graphics and Applications Magazine
Computer graphics hardware and software, display technology, computational geometry, geometric data structures and databases, industrial applications, animation methodology, human factors for graphics, interactive graphics languages, graphic arts, graphics support of MIS, and distributed graphics techniques. (6)
Peter R. Wilson, Rensselaer Polytechnic Institute, Center for Interactive Computer Graphics, Troy, N.Y. 12180 518-276-6751

Computer Magazine
Survey and tutorial articles covering a broad range of computer hardware, software, and system design and application; special issues focus on such topics as VLSI design, software engineering, local area networks, computer communications, and computer architecture. Regular departments present new product announcements, book reviews, and professional calendar. (12)
Jon T. Butler, U.S. Naval Postgraduate School, Dept. of ECE, Code 62-BU, Monterey, Calif. 93943 408-646-3299

Computers, IEEE Trans.
Design and analysis of algorithms, computer systems, and digital networks; methods for specifying, measuring, and modeling the performance of computers and computer systems; design of computer components, such as arithmetic units, data storage devices, and interface devices; design of reliable and testable digital devices and systems; computer networks and distributed computer systems; new computer organizations and architectures; applications of VLSI technology to computers; human factors and interactive computer systems; application of computer technology to other disciplines such as automatic control, robotics, communication or real-time information processing, and instrumentation.
Earl Swartzlander, Dept. ECE, University of Texas, Austin, Texas 78712 512-471-5923

Consumer Electronics, IEEE Trans.
The design and manufacture of consumer electronics products, components, and related activities, particularly those used for entertainment, leisure, and educational purposes. (4)
Wayne C. Luplow, Zenith Electronics Corp., 1000 Milwaukee Ave., Glenview, Ill. 60025 312-391-7873

Control Systems Magazine
Control system applications and experiences, design tools, conference programs, educational features, book reviews, and Society news items. Oriented toward practicing control system engineers. (7)
Herbert Rauch, Lockheed 92-30/250, 3251 Hanover St., Palo Alto, Calif. 94304 415-424-2704

Design and Test of Computers Magazine
Covers methods, practical experience, research ideas, and commercial products that aid in the design and test of chips, assemblies, and systems—e.g., design automation, CAD workstations, design software, computer-aided test, test equipment, self-test, and design for testability. (4)
Manuel A. d'Abreau, General Electric Co., RD, Building KW C308, Box 8, Schenectady, N.Y. 12301

Education, IEEE Trans.
Educational methods, technology, and programs; history of technology; impact of evolving research on education. (4)
Prof. Frank Barnes, Dept. of Electrical and Computer Engineering, University of Colorado, Campus Box 425, Boulder, Colo. 80309-0425 303-492-5071

Electrical Insulation, IEEE Trans.
Electrical insulation common to the design and construction of components and equipment for use in electric and electronic circuits and distribution systems at all frequencies. (6)
Arend van Roggen, RD 2, Kennett Square, Pa. 19348 215-388-6909

Electrical Insulation Magazine
Compilation of articles and news that relate to in-

sulation and dielectrics. Includes conference activities reporting and papers of general interest. (6)
J.A. Tanaka, University of Connecticut, Chemistry Dept./U-60, Room 151, 215 Glenbrook Rd., Storrs, Conn. 06269-3060 203-486-2443

Electromagnetic Compatibility, IEEE Trans.
EMC standards; measurement technology; undesired sources; cable/grounding; filters/shielding; equipment EMC; systems EMC; antennas and propagation; spectrum utilization; electromagnetic pulses; lightning; radiation hazards; and Walsh functions. (4)
Motohisa Kanda, Electromagnetic Fields Division, National Bureau of Standards, Boulder, Colo. 80303 303-497-5320

Electron Device Letters
Theory, design, and performance of electron and ion devices, solid-state devices, integrated electronic devices, optoelectronic devices, and energy sources. Publication time is two months from the end of the month in which manuscript is received. (12)
John Brews, Dept. of Electrical and Computer Engineering, Room 230, Building 104, University of Arizona, Tucson, Ariz. 85721
602-621-8734

Electron Devices, IEEE Trans.
The theory, design, and performance of active electron and ion devices, solid-state devices, integrated electron devices, and energy sources. (12)
Renuka Jindal, AT&T Bell Labs, Room 14A-325, 67 Whippany Rd., Whippany, N.J. 07981
201-386-3084

Electronic Materials, IEEE J.
Applications of semiconductors, magnetic alloys, insulators, and optical and display materials. (12)
Theodore C. Harman, MIT Lincoln Laboratory, Lexington, Mass. 02173 617-981-4418

Energy Conversion, IEEE Trans.
Research, development, design, application, construction, installation, and operation of electric power generating facilities (along with their conventional, nuclear, or renewable sources) for the safe, reliable, and economic generation of electrical energy for general industrial, commercial, public, and domestic consumption. (4)
Harold Gold, 1037 North Primrose, Rialto, Calif. 92376 714-875-8117
For information on manuscript submission: Nancy Heitmann, Society Special Services of Technical Activities Dept., IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331
908-562-3881

Engineering Management, IEEE Trans.
Management of technical functions such as research, development, and engineering in industry, government, university, and other settings. Emphasis is on studies carried on within an organization to help in decision making or policy formation for RD&E. (4)
Dundar F. Kocaoglu, Engineering Management Program, School of Engineering and Applied Science, Portland State University, Portland, Ore. 97207-0751 503-464-4660

Engineering Management Review
A reprint of selected papers relevant to engineering management. (4)
David S. Lewis, Box 18438, Irvine, Calif. 92713
714-633-9660

Engineering in Medicine and Biology Magazine
Contains general and technical short articles on current technologies and methods used in Biomedical and Clinical Engineering. Current news items, book reviews, patent descriptions, and a correspondence section are included. (4)
A.S. Wald, Dept. of Anesthesiology, Columbia-Presbyterian Medical Center, 630 W. 168th St., New York, N.Y. 10032 212-305-2164

Expert Magazine (Intelligent Systems and Their Applications)
Tutorial and survey articles on the current applications of intelligent systems, including databases, expert systems, and artificial intelligence. (6)
B. Chandrasekaran, Ohio State University, Computer and Information Sciences Dept., Room 217, Bolz Hall, 2036 Neil Ave., Columbus, Ohio 43210-1277

Geoscience and Remote Sensing, IEEE Trans.
Theory, concepts, and techniques of science and engineering as applied to sensing the earth, oceans, atmosphere, and space; and the processing, interpretation, and dissemination of this information. (6)
James A. Smith, Terrestrial Physics Laboratory, Code 920, NASA/Goddard Center, Greenbelt, Md. 20771 301-286-4950

Image Processing, IEEE Trans.
Signal-processing aspects of image processing, imaging systems, and image scanning, display, and printing. Includes theory, algorithms, and architectures for image coding, filtering, enhancement, restoration, segmentation, and motion estimation; image formation in tomography, radar, sonar, geophysics, astronomy, microscopy, and crystallography; image scanning, digital half-toning and display, and color reproduction. (4)
David C. Munson, Coordinated Science Laboratory, 1101 W. Springfield Ave., Urbana, Ill. 61801
217-333-4789

Industrial Electronics, IEEE Trans.
All aspects of the theory and applications of industrial electronics and control instrumentation science and engineering, including microprocessor control systems, high-power controls, process control, programmable controllers, numerical and program control systems, flow meters, and identification systems. (6)
James C. Hung, Dept. of Electrical and Computer Engineering, University of Tennessee, Knoxville, Tenn. 37996 615-974-5420

Industry Applications, IEEE Trans.
The development and application of electric systems, apparatus, devices, and controls to the processes and equipment of industry and commerce; the promotion of safe, reliable, and economic installations; the encouragement of energy conservation; and the creation of voluntary engineering standards and recommended practices. (6)
Edward A.E. Rich, 243 Juniper Dr., Schenectady, N.Y. 12306 518-372-9572

Information Theory, IEEE Trans.
The fundamental nature of the communication process; transmission and utilization of information; coding and decoding of digital and analog communication transmissions; study of random interference and information-bearing signals; and the development of information-theoretic techniques in diverse areas, including communication systems, detection systems, pattern recognition, learning, and automata. (6)
Bruce Hajek, Coordinated Science Laboratory, University of Illinois, 1101 W. Springfield Ave., Urbana, Ill. 61801 217-333-3605

Instrumentation and Measurement, IEEE Trans.
Measurements and instrumentation utilizing electrical and electronic techniques. (6)
Ed Richter, 32 Brewster Lane, Acton, Mass. 01720 508-263-7256

Knowledge and Data Engineering, IEEE Trans.
Artificial intelligence techniques, including speech, voice, graphics, images, and documents; knowledge and data engineering tools and techniques; parallel and distributed processing; real-time distributed processing; system architectures, integration, and modeling; database design, modeling, and management; query design, and implementation languages; distributed database control; statistical databases; algorithms for data and knowledge management; performance evaluation of algorithms and systems; data communications aspects; system applications and experience; knowledge-based and expert systems; and integrity, security, and fault tolerance. (6)
C.V. Ramamoorthy, Computer Science Division, University of California, Berkeley, Calif. 94720
415-642-4751

IEEE LTS: The Magazine of Lightwave Telecommunications Systems
Covers all aspects of the use of lightwave technologies in communication systems and networking, focusing on systems, architectures, standards, and applications. Topics include coherent communications, broadband and photonic systems and applications, optical systems for TV transport and distribution, optical local to wide area networking, optical interconnects, optical undersea and terrestrial communication systems, and passive photonic network technologies. (4)
Larry L. Campbell, 9109 Jeffrey Rd., Great Falls, Va. 22066 703-759-4199

Lightwave Technology, J.
All aspects of optical guided-wave science, technology, and engineering in the areas of fiber and cable technologies; active and passive guided-wave componentry (light sources, detectors, repeaters, switches, fiber sensors, etc.); integrated optics and optoelectronics; systems and subsystems; new applications; and unique field trials. (12)
Donald Keck, Corning Glass Works, SP FR 29, Corning, N.Y. 14831 607-974-3726

Magnetics, IEEE Trans.
Science and technology related to the basic physics of magnetism, magnetic materials, applied magnetics, magnetic devices, and basic and applied superconductivity. (6)
Carl E. Patton, Dept. of Physics, Colorado State University, Fort Collins, Colo. 80523
303-491-5083

Medical Imaging, IEEE Trans.
Imaging of body organs, usually in situ, rather than microscopic biological entities; the associated equipment and techniques, such as instrumentation systems, transducers, computing hardware, and software. (4)
A. Bertrand Brill, Dept. of Nuclear Medicine, University of Massachusetts Medical Center, 55 Lake Ave. N., Worcester, Mass. 01655
508-856-4236

Micro Magazine
Microprocessor technology; computer-aided design; system support software, interfacing techniques, chip design, and fabrication; personal computing;

control hierarchies, architectures, applications and draft standards for hardware, software, and interconnections. (6)

Dante Del Corso, Politecnico di Torino, Dipart. di Electr., C. Duca degli Abruzzi, 24, Torino 10129, Italia

Microelectromechanical Systems, IEEE J.
Micromechanics, Microdynamics, Microelectromechanical Systems, MEMS: articles on small devices—from microns to millimeters; microfabrication techniques; microphenomena; microrobots; microbatteries, microbearings; and other microcomponents; theoretical, computational, modeling and control results; new materials and designs; tribology; microtelemanipulation; and applications such as biomedical engineering, optics, and fluidics. (4)

William Trimmer, Belle Mead Research Inc., 55 Riverview Terrace, Belle Mead, N.J. 08502

Microwave and Guided Wave, IEEE Letters
Published monthly with the purpose of providing fast publication of original and significant contributions relevant to all aspects of microwave/millimeter-wave technology. Emphasis is on devices, components, circuits, guided-wave structures, systems and applications covering the frequency spectrum from microwave and beyond, including submillimeter-waves and infrared. Publication time will be two months from the end of the month in which a contribution was received, provided the author responds immediately to all communications. Acknowledgment letters will not be sent to the authors. Galley proofs will be sent, but in the interest of fast publication, there may not be time to wait for their return. Errata will be published in the next issue if sent promptly. Lengths of the letters are expected to be no longer than two printed pages. (12)

Tatsuo Itoh, Dept. of Electrical and Computer Engineering, University of California, 66-147 A Engineering IV, 405 Hilgard Ave., Los Angeles, Calif. 90024 213-206-4820

Microwave Theory and Techniques, IEEE Trans.
Microwave theory, techniques, and applications as they relate to components, devices, circuits, and systems involving the generation, transmission, and detection of microwaves. (12)

Stephen Maas, EE Dept., 56-125B Engineering IV, UCLA, Los Angeles, Calif. 90024 213-206-1668

Network Magazine (The Magazine of Computer Communications)
Network protocols and architecture; protocol design and validation; communications software; network control, signaling, and management; network implementation (LAN, MAN, WAN); and micro-to-host communications. (6)

Warren S. Gifford, Bellcore, 331 Newman Springs Rd., Room 1C401, Red Bank, N.J. 07701 201-758-2200

Neural Networks, IEEE Trans.
High-quality papers in the theory, design, and application of neural networks, ranging from software to hardware. Emphasis will be given to artificial neural networks. Readers are encouraged to submit manuscripts that disclose significant technical achievements, indicate exploratory developments, or present significant applications for neural networks. This Transactions contains a Letters section intended to serve as a vehicle for rapid publication of new, significant, and timely research results. The Letters section also includes information of current interest, and comments and rebuttals in connection with published papers. (6).

Robert Marks, Dept. of Electrical Engineering, University of Washington, Seattle, Wash. 98195 206-543-6990

Nuclear Science, IEEE Trans.
All aspects of the theory and applications of nuclear science and engineering, including instrumentation for the detection and measurement of ionizing radiation; particle accelerators and their controls; nuclear medicine and its application; effects of radiation on materials, components, and systems; reactor instrumentation and controls; and measurement of radiation in space. (6)

Dick A. Mack, 600 Lockwood Lane, Santa Cruz, Calif. 95066 408-438-0200

Oceanic Engineering, IEEE J.
Bayes procedures; buried-object detection; dielectric measurements; Doppler measurements; geomagnetism; sea floor; sea ice; sea measurements; sea surface electromagnetic scattering; seismology; sonar; acoustic tomography; underwater acoustics; and underwater radio communication. (4)

Frederick H. Fisher, Marine Physical Laboratory, Scripps Institution of Oceanography, University of California, La Jolla, Calif. 92093 619-534-1796

Parallel and Distributed Systems, IEEE Trans.
Architectures—design, analysis, and implementation of multiprocessor systems (including multiprocessors, multicomputers, and networks); impact of VLSI on system design; interprocessor communications. Software—parallel languages and compilers; scheduling and task partitioning; databases, operating systems, and programming environments for multiple-processor systems. Algorithms and applications—models of computation; analysis and design of parallel/distributed algorithms; application studies resulting in better multiple-processor systems. Other issues—performance measurements, evaluation, modeling and simulation of multiple-processor systems; real-time, reliability and fault-tolerance issues; and conversion of software from sequential to parallel forms. (6)

Tse-Yun Feng, Dept. of EE, Engineering East Building, Pennsylvania State University, University Park, Pa. 16802 814-863-1469

Pattern Analysis and Machine Intelligence, IEEE Trans.
Statistical and structural pattern recognition; image analysis; computational models of vision; computer vision systems; enhancement, restoration, segmentation, feature extraction, shape and texture analysis; applications of pattern analysis in medicine, industry, government, and the arts and sciences; artificial intelligence, knowledge representation, logical and probabilistic inference, learning, speech recognition, character and text recognition, syntactic and semantic processing, understanding natural language, expert systems, and specialized architectures for such processing. (12)

Anil Jain, Dept. of Computer Science, A-726 Wells Hall, Michigan State University, East Lansing, Mich. 48824 517-353-5150

Photonics Technology, IEEE Letters
Rapid publication of original research relevant to photonics technology. This expanding field emphasizes laser and electro-optic technology, laser physics and systems, applications, and photonic/lightwave components and applications. The journal offers short, archival publication with minimal delay. (12)

Paul W. Shumate, Bellcore 2L-287, 445 South St., Morristown, N.J. 07960 201-829-4600

Plasma Science, IEEE Trans.
Plasma science and engineering, including: magnetofluid dynamics and thermionics; plasma dynamics; gaseous electronics and arc technology; controlled thermonuclear fusion; electron, ion, and plasma sources; space plasmas; high-current relativistic electron beams; laser-plasma interactions; diagnostics; plasma chemistry and colloidal and solid-state plasmas. (6)

Steven J. Gitomer, Office of Arms Control, U.S. Dept. of Energy, DP-5.2, Forrestal Building, 1000 Independence Ave., S.W., Washington, D.C. 20585

Power Delivery, IEEE Trans.
Research, development, design, application, construction, the installation and operation of apparatus, equipment, structures, materials, and systems for the safe, reliable, and economic delivery and control of electric energy for general industrial, commercial, public, and domestic consumption. (4)

Harold Gold, 1037 North Primrose, Rialto, Calif. 92376 714-875-8117

For information on manuscript submission: Nancy Heitmann, Society Special Services of Technical Activities Dept., IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331 908-562-3881

Power Electronics, IEEE Trans.
Fundamental technologies used in the control and conversion of electric power. Topics include dc-to-dc converter design, direct off-line switching power supplies, inverters, controlled rectifiers, control techniques, modeling, analysis and simulation techniques, the application of power circuit components (power semiconductors, magnetics, capacitors), and thermal performance of electronic power systems. (4)

Richard Hoft, Electrical and Computer Engineering Dept., University of Missouri, 223 Electrical Engineering, Columbia, Mo. 65211 314-882-3491

Power Engineering Review
Electric power system engineering; includes one-page summaries of all papers accepted for publication in **Energy Conversion**, **Power Delivery**, and **Power Systems**. Also includes the Power Engineering Society Newsletter, selected prize papers, high-interest papers, and other articles of technical interest. (12)

C.J. Essel, 5969 W. 76th St., Los Angeles, Calif. 90045 213-645-3380

Power Systems, IEEE Trans.
Requirements, planning, analysis, reliability, operation, and economics of electrical generating, transmission, and distribution systems for industrial, commercial, public, and domestic consumption.(4)

Harold Gold, 1037 North Primrose, Rialto, Calif. 92376 714-875-8117

For information on manuscript submission: Nancy Heitmann, Society Special Services of Technical Activities Dept., IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331 908-562-3881

Professional Communication, IEEE Trans.
The study, development, improvement, and promotion of techniques for preparing, organizing for use, processing, editing, collecting, conserving, and disseminating any form of information in the electrical and electronics fields. (4)

Dr. Scott Sanders, Dept. of English Language and Literature, University of New Mexico, Albuquerque, N.M. 87131 505-345-5705

Quantum Electronics, IEEE J.
Generation, amplification, modulation, detection,

waveguiding, or techniques and effects that can affect the propagation characteristics of coherent electromagnetic radiation having submillimeter and shorter wavelengths. (12)

Steven R.J. Brueck, Center for High Technology Materials, University of New Mexico, EECE Bldg., Rm. 125, Albuquerque, N.M. 87131
505-277-6033

Reliability, IEEE Trans.
Principles and practices of reliability, maintainability, and product liability pertaining to electrical and electronic equipment. (5)

Dr. Michael Pecht, Mechanical Engineering Dept., University of Maryland, College Park, Md. 20742
301-405-5278

Robotics and Automation, IEEE Trans.
Theory and applications in robot dynamics and control; simulation of robots and manufacturing systems; robot languages; robotic vision and other sensory interfaces; manipulator design; robot locomotion; management of multirobot systems; geometric modeling, other computer-aided design techniques; robot manufacturing; motion planning, task planning, and expert systems in robotics and automation; hardware and software implementation of robotic systems. (6)

Russell H. Taylor, Manufacturing Research Dept., IBM T.J. Watson Res. Cntr., Box 704, Yorktown Heights, N.Y. 10598 914-945-3693

Semiconductor Manufacturing, IEEE Trans.
Process control techniques; process modeling, simulation, measurements, diagnostics; defect characterization and control; yield analysis and modeling; product design for manufacturability, reliability; product transfer from development to manufacturing; factory design, simulation; automation: models, algorithms, equipment interfaces, etc.; equipment design: modeling and simulation; production control and scheduling; operations management: training, incentives, productivity measures; standards: materials, processes; computer integration: computer-controlled equipment and facilities; and the application of AI and expert systems. (4)

Costas Spanos, 568 Cory Hall, University of California, Berkeley, Calif. 94720
415-643-6776

Signal Processing, IEEE Trans.
Transmission, recording, reproduction, processing, and measurement of speech and other signals by digital, electronic, electrical, acoustic, mechanical, and optical means; the components and systems to accomplish these and related aims; and the environmental, psychological, and physiological factors of these technologies. (12)

Pierce Wheeler, RD 3, Box 363, Chester, N.J. 07930 908-879-5746

Signal Processing Magazine
Acoustics, including digital audio, underwater signal processing, and electroacoustics; speech, including speech transmission and coding; enhancement and noise reduction; analysis and reconstruction; synthesis; recognition; production/synthesis; performance evaluation; signal processing, one-dimensional and multidimensional digital signal processing, including discrete Fourier and other transforms; nonlinear analysis; spectral analysis; signal and system identification; filter design and applications; applications to echo cancellation, aids for the handicapped, and radar; image processing; sensor array processing; multidimensional processing; VLSI; and hardware implementations. (4)

Jack Deller, EE Dept., 260 Engineering Building, Michigan State University, East Lansing, Mich. 48824-1226 517-353-8840

Software Engineering, IEEE Trans.
Specification, development, management, test, maintenance, and documentation of computer software. (12)

Victor Basili, Dept. of Computer Science, A.V. Williams Building, Room 411, University of Maryland, College Park, Md. 20742 301-405-2668

Software Magazine
Tutorials and surveys on current techniques and new products in software design and development. Focuses on such topics as software tools, measuring program reliability, designing software tests, PCs as programming workstations, localization of bugs, and making programs readable. (6)

Carl K. Chang, University of Illinois, Dept. EECS, M/C 154, Box 4348, Chicago, Ill. 60680
312-996-4860

Solid-State Circuits, IEEE J.
Analysis, design, and performance of solid-state circuits; transistors; diodes; bulk-effect and magnetic devices; digital; analog; microwave; optoelectronic; integrated circuits; and large-scale integration. (12)

Harry E. Mussman, MS48, Switching Dept., GTE Laboratories Inc., 40 Sylvan Rd., Waltham, Mass. 02154 617-466-2410

Systems, Man, and Cybernetics, IEEE Trans.
Large-scale systems, theory and applications; optimization; decision analysis; problem definition; modeling; simulation; testing; evaluation; foundations of cybernetics; pattern recognition; adaptive and learning systems; and biocybernetics. (6)

Andrew P. Sage, School of Information Technology & Engineering, George Mason University, 4400 University Dr., Fairfax, Va. 22030
703-993-1500

Technology and Society Magazine
Impact of technology (as embodied by the fields of interest of IEEE) on society, including both positive and negative effects; the impact of society on the engineering profession, the history of the societal aspects of electrotechnology, and professional, social; and economic responsibility in the practice of engineering and its related technology. (4)

Leon Zelby, Dept. of EE, 202 W. Boyd, University of Oklahoma, Norman, Okla. 73019
405-325-4290

Ultrasonics, Ferroelectrics and Frequency Control, IEEE Trans.
Acoustic holography and imaging; acousto-optic interactions; biological and medical applications; filters and resonators; industrial applications; nondestructive evaluation; physical acoustics; piezoelectric and magnetostrictive materials; surface-acoustic-wave-based systems; surface-acoustic-wave devices; and underwater sound. (6)

William D. O'Brien, Bioacoustics Research Lab, Dept. of Electrical & Computer Engineering, University of Illinois, 1406 West Green St., Urbana, Ill. 61801
217-333-2407

Vehicular Technology, IEEE Trans.
Land, airborne, and maritime mobile services; portable or hand-carried and citizen's communications services, when used as an adjunct to a vehicular system; vehicular electrotechnology, equipment, and systems ordinarily identified with the automotive industry. (4)

Sang B. Rhee, AT&T Bell Laboratories, Room 2F-203, Whippany Rd., Whippany, N.J. 07981
201-386-6796

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Rice University Department of Electrical and Computer Engineering invites applications for faculty positions in the areas of robotics, signal processing, and computer systems. Applicants in the area of robotics should be interested in space or undersea applications and be able to lead a robotics laboratory. Applicants in signal processing should have a background in basic signal and systems with interests in image and multidimensional processing. Applicants in the computer systems area should have interests in the general areas of computer architecture, operating systems, and parallel computing. Outstanding applicants working in related areas will also be considered. Rice University is a small, private university with a strong commitment to excellence in both teaching and research. Rice is located in Houston, Texas, a city with affordable housing and excellent fine arts. Applicants should submit their resume, a summary of their research accomplishments, and the names of at least three references to the Chairman of the Department of Electrical and Computer Engineering, Rice University, P.O. Box 1892, Houston, TX 77251-1892. Rice University is an equal opportunity/affirmative action employer.

University of Arizona. The University of Arizona Electrical and Computer Engineering Department invites applications for one or more tenure track faculty appointments for the 1992-93 academic year. Preference will be given to applicants at the Assistant Professor level, but exceptional candidates at higher levels may also be considered. In addition to an earned doctorate and a commitment to effective teaching at both the undergraduate and graduate level, it is essential that candidates have outstanding research achievement and/or potential and the commitment and ability to establish an externally sponsored research program. Technical areas of particular interest for 1992-93 recruiting are: (1) computer engineering emphasizing VLSI design and test and/or interconnection networks for parallel and distributed processing systems; (2) communications systems: (3) and microelectronics emphasizing microelectronics manufacturing and/or semiconductor processing science. Applicants should send a resume, a statement of teaching and research interests, and a list of three references to: Prof. K.F. Galloway, Department Head, Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ 85721. Applications will be reviewed starting January 15, 1992 and will be received until open positions are filled. The University of Arizona is an Equal Opportunity/Affirmative Action Employer and specifically invites women and minorities to apply.

Montana State University seeks qualified candidates at the Assistant Professor level in two areas: 1) logic circuits and microprocessor applications with specialization in digital signal processing or VLSI design; and 2) electronics with specialization in power electronics. Applicants must hold an earned Ph.D. degree in Electrical Engineering or closely related field, have specialization in one of the two areas listed above, and have demonstrated potential for teaching at the undergraduate and graduate levels and for developing an independent research program. Industrial experience is desirable. The Electrical Engineering Department offers programs leading to BS, MS and Ph.D. degrees. Curriculum vitae, a list of 3 references and a statement about teaching philosophy and research interests should be addressed to: Dr. Donald A. Pierre, Head, Electrical Engineering Search Committee, Department of Electrical Engineering, Montana State University, Bozeman, MT 59717-0378. Applications must be postmarked by February 15, 1992. Montana State University is an AA/EO Employer, and preference is given to eligible veterans.

Electrical Engineering: The Department of Electrical Engineering at Memphis State University is now accepting applications for tenure-track faculty positions. Preference will be given to applicants for the Assistant or Associate Professor level. Applicants with research specializations in computer engineering, biomedical engineering, or electro-optics are preferred. Candidates should be available for employment by August 20, 1992. Research experience and potential for securing funded research will be important considerations in candidate selection. An earned doctorate in electrical engineering or related area is required. Interested applicants should send resumes with names, addresses, and telephone numbers of three references to: Dr. Carl E. Halford, Department of Electrical Engineering, Memphis State University, Memphis, TN 38152. Closing date for applications is January 31, 1992, with initial screening to begin at that time. However, if needed, applications will be reviewed until positions are filled. Equal opportunity, affirmative action employer. Successful candidates must meet Immigration Reform Act criteria.

The Electrical and Computer Engineering Department of the University of South Carolina invites applications for faculty positions in the areas of artificial intelligence, computer architecture and computer vision. Applicants must have a Ph.D. in either Electrical Engineering, Computer Engineering or Computer Science. Applicants must have legal authority to work permanently in the U.S. The University of South Carolina, as the flagship university of the state, seeks candidates having a strong commitment to excellence in both education and research. Successful candidates are expected to demonstrate strong research potential. Please submit complete resume and the names of three references to Professor Ronald D. Bonnell, Electrical and Computer Engineering Department, University of South Carolina, Columbia, SC 29208. Closing date for applications is February 1, 1992. The University of South Carolina is an Affirmative Action/Equal Opportunity Employer.

Purdue University School of Electrical Engineering invites applications for tenure-track faculty positions at all ranks. Primary need is for faculty with specialization in the areas of computers, microelectronics, and optics; but all specialities will be considered. Responsibilities will include both teaching and research. Salary is commensurate with qualifications and experience. Applicants must possess a doctorate degree. Send a resume, including a statement of teaching and research interest and a list of three (3) references to: Head, School of Electrical Engineering, Purdue University, West Lafayette, IN 47907. Purdue University is an Equal Opportunity/Affirmative Action employer.

The University of Cincinnati, Electrical and Computer Engineering Department. Applications are solicited for new tenure track faculty positions at all ranks in the Systems Engineering and Computing Systems Programs of the Department. The primary areas of interest in Systems Engineering are: control systems, with emphasis on applied research in robust, multivariable, intelligent, nonlinear and adaptive control; Intelligent computer vision, including artificial neural networks and their applications in image analysis and understanding; digital communication systems with emphasis on optical signal processing, optical computing, and communication; and digital signal processing, with emphasis on detection and estimation and statistical signal processing. The primary areas of interest in computer science and engineering are: software engineering, parallel and distributed computing, VLSI systems and computer aided design, microprocessor and digital hardware systems design, computer networks and communications, and fault tolerance systems. The Department offers B.S., M.S., and Ph.D. programs in both Electrical and Computer Engineering. Currently the department has 30 full-time faculty, 160 full-time graduate students, 400 undergraduate students, 2 major research centers, and 20 full-time staff members, and graduates 35 M.S. and 15 Ph.D.s per year. Externally funded research is currently at $4.0M annually and growing. The Department is very well equipped in both teaching and research labs in the signal processing and computer vision, automatic controls, and computer systems design areas with state-of-the-art networked computing facilities. Faculty are provided a reduced teaching load and a start-up package including office computers/Sun workstations/laser printers, research equipment, summer salary, individual lab space, graduate student support, and conference travel. The University is supportive of the Department in providing an environment conducive to the establishment of an academic and professional career. All candidates should have a strong commitment to excellence in research and teaching and an earned Ph.D. Please send curriculum vitae to: Dr. Vik J. Kapoor, Head, Electrical and Computer Engineering Department, University of Cincinnati, Cincinnati, Ohio 45221-0030. E-mail vkapoor@uceng.uc.edu. The University of Cincinnati is an Affirmative Action/Equal Opportunity employer and encourages and welcomes applications from women and minorities.

Michigan Technological University is seeking candidates for Electrical Engineering faculty positions (Ph.D. required) with primary consideration in the areas of power systems, automatic control, and computer hardware. Exceptional candidates in other areas will be considered. Candidates must provide evidence of dedication to excellent teaching and the ability to initiate and lead research programs that are highly valued in industrial or aerospace applications. Salary is commensurate with experience and rank. Send resume to P.H. Lewis, Appointments Committee Chairman, Department of Electrical Engineering, Michigan Technological University, Houghton, MI 49931. Michigan Technological University is an Affirmative Action/Equal Opportunity Employer.

Department of Electrical and Computer Engineering, Northeastern University in Boston seeks tenure track faculty, at all professional levels, in the areas of Computer Engineering (computer architecture, software engineering, VLSI systems design for test and fault tolerance), robotics, digital signal processing (speech processing and image processing), microelectronics (analog and digital systems design and fabrication), control systems, power systems, electromagnetics and optics. The ECE Department currently has forty-nine full-time faculty, two nationally and internationally recognized research centers, a large and expanding graduate program, and sponsored research exceeding five million dollars annually. Expansive opportunities for research exist due to one of the highest concentrations of high technology in the nation. Ph.D. in Electrical En-

gineering, Computer Engineering, Computer Science or related field required with previous academic or industrial experience preferred. Salary and rank are commensurate with experience. Send resumes to: John G. Proakis, Chairman, Electrical and Computer Engineering, 309 Dana Research Building, Northeastern University, 360 Huntington Avenue, Boston, MA 02115.

Professor, Department of Electrical Engineering, University of Texas at El Paso. The Dept of Electrical Engineering of the University of Texas at El Paso is seeking applications and/or nominations to fill a senior faculty position in the area of computer engineering. The Dept is seeking an established researcher/educator to assume a leadership role in the continued development of its program in this area. Applicants should have a Ph.D. in either electrical or computer engineering. The appointee will be expected to establish & maintain a strong program of research, including extramural funding, develop & teach computer engineering courses at both the graduate and undergraduate level, & provide leadership & mentoring to faculty members & graduate students in computer engineering. The position is available 09-01-92; applications will be reviewed starting 01-31-92. Complete resume with listing of three references (name, address, telephone) should be sent to Dr. Michael E. Austin, Dept of Electrical Engineering, University of Texas at El Paso, El Paso, TX 79968-0523. The University is an EO/AA employer.

Wieseman Chair in Computer Science at Lehigh University in Bethlehem, Pennsylvania. The Department of Computer Science and Electrical Engineering is looking for an exceptional individual to fill this position at the rank of Professor by August 1992. We are interested in candidates with established research records, dedication to excellence in graduate and undergraduate education and with demonstrated potential for leadership in the field of computer science. The Department has an excellent undergraduate program as well as a strong and expanding graduate program at the MS and PhD levels. The primary research concentrations in computer science are in artificial intelligence applications, natural language, knowledge based systems, programming languages, and parallel processing. The Department plans to continue building on these areas of strength as well as expanding into new areas. There are 28 faculty and 180 graduate students in the Department, including both computer science and electrical engineering. Departmental laboratory facilities include a network of Sun workstations, Unix minicomputers, a hypercube, Symbolics machines and PCs, and an Intel microcomputer development laboratory. Lehigh University is an affirmative action/equal opportunity employer. Women and minorities are encouraged to apply. Candidates should send a curriculum vita and list of references to Professor D.R. Decker, Wieseman Chair Search Committee, Department of Computer Science and Electrical Engineering, Lehigh University, Bethlehem, Pennsylvania 18015.

The School of Engineering Science located at Simon Fraser University is seeking a senior faculty candidate in control, robotics, and automation. Prior industrial experience and an interest in electromechanical design would also be an asset. A strong research record is essential. The successful applicant will join a small research group working on topics related to automation engineering, and will also teach two courses per annum in his or her areas of expertise, supervise graduate students and participate in industrial interactions. Rank and salary will be competitive. Engineering Science provides an exciting educational environment demanding high academic standards of its students. Local industry offers many opportunities for faculty research and strong industrial links are characteristic of the program and expected of faculty members. This academic environment is balanced by the natural and cultural ambience of one of the most attractive cities in North America. Moreover, the university itself enjoys a spectacular mountaintop setting, a short drive from downtown Vancouver. Preference will be given to candidates who are eligible for employment in Canada at the time of application. Applications from other candidates are welcome but consideration of such candidates must be deferred until a Canadian search is complete. Positions are subject to budgetary authorization. Simon Fraser University is committed to the principle of equity in employment and offers equal employment opportunities to qualified applicants. To apply, send a curriculum vitae and the names of three references to Dr. J.K. Cavers, Director, School of Engineering Science, Simon Fraser University, Burnaby, B.C. V5A 1S6.

Faculty Positions—Clemson University: 1. The Department of Electrical and Computer Engineering seeks candidates for a tenure track position in Computer Engineering with a specific interest in the area of computer architecture. It is desired that this position be filled by a person interested in quantitative approaches who can benefit from and complement existing strengths in quantitative performance analysis. 2. Applicants in other areas, synergistic with the Holcombe Chair in Electronic Communications Systems, may also be considered. Candidates should have a Ph.D. in Electrical or Computer Engineering or Computer Science and have a strong interest in teaching at both the undergraduate and graduate levels. Clemson University's College of Engineering was listed as one of the United States' "up-and- coming" engineering graduate programs in the March 19, 1990 of the U.S. News and World Report. The ECE Department has 38 full-time faculty, approximately 500 undergraduate students, and 150 graduate students. It offers B.S., M.S., and Ph.D. degrees in both electrical engineering and computer engineering. Facilities and research groups include the Clemson University Electric Power Research Association (CUEPRA); a microncircuits reliability research group with a class 100 clean room; automated microwave measurement facilities to 25 Ghz; an image processing laboratory; and a Center for Computer Communications Systems. Interested persons should send a curriculum vita and the names of at least three references to L. Wilson Pearson, Head, Department of Electrical and Computer Engineering, Clemson University, Clemson, South Carolina 29634-0915. Consideration of candidates will begin on February 15, 1992 and will continue until positions (s) is (are) filled. Clemson University is an Equal Opportunity/Affirmative Action Employer.

Stocker Visiting Chair in Electrical and Computer Engineering at Ohio University. Applications and nominations are being accepted for the position of Stocker Visiting Professor in Electrical and Computer Engineering (ECE). The ECE Department at Ohio University has twenty-two (22) full-time and four (4) part-time faculty, 400 undergraduate students and 80 graduate students. External research support in ECE exceeds $3.1M per year, a large portion of which comes via the Avionics Engineering Center, a unit of ECE. The ECE Department is housed in the $15M Stocker Engineering Center. The Stocker Chair position is supported through the Stocker Endowment, presently worth more than $13M. Qualifications for consideration for the Stocker Chair position include prominent achievements in research and teaching or industry/government. The individual selected for this position is expected to teach, participate in Departmental research, and be available to present and conduct invited seminars/lectures at various universities, including O.U. The maximum term of appointment for this position is three (3) years; a lesser term can be negotiated. In filling the Stocker Chair position, preference will be given to those who have a permanent base of employment and plan to return there upon completion of the Stocker Chair appointment. Applications and nominations will be accepted until the position is filled. Please send a resume with at least three (3) references or your nomination to Dr. Jerrel R. Mitchell, Stocker Center, Ohio University, Athens, Ohio 45701-2979. Ohio University is an equal opportunity and affirmative action employer.

Information System Scientist. Center of Excellence for Information Technology and Decision Making, Carnegie Mellon University, Pittsburgh, PA. The Center of Excellence for Information Technology and Decision Making at Carnegie Mellon University invites applications for the position of Information System Scientist. The research mission of the Center of Excellence is to develop advances in the theories, methodologies, and tools of information science in relation to decision making and coordination in complex organizations. The research focus of the Center of Excellence includes the areas of knowledge-based systems, artificial intelligence, human-computer Interfaces, and decision support systems. Specific research interests include cognitive modelling, knowledge representation and acquisition, machine learning, planning, problem solving, coordination, and scheduling, and the impact of information technology on organizational structures and processes. Potential candidates will have a doctorate in Information Science or a closely related field, and demonstrated capability in the performance of basic research. The Information System Scientist will be expected to contribute to the program of the Center of Excellence by conducting research in his/her area of specialty and interest. CMU is highly respected for the quality of its academic and research programs in computer science, robotics, cognitive psychology, economics, business and engineering. The Information System Scientist will have the opportunity to interact with faculty and staff in related basic and applied research programs and to pursue inter-disciplinary links with his/her research program. Applicants are requested to provide a resume, description of research area capabilities and interests, representative technical publications, and reference information. Replies should be forwarded to: Dr. Jay Warshawsky, Co-director, Center of Excellence for Information Technology and Decision Making, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213-3890.

Graduate Associateships in Avionics Engineering or power electronics/industrial control. Associateships are available for M.S. or Ph.D. students in Electrical Engineering specializing in these areas. Students will be expected to perform research on funded or related projects within the Avionics Engineering Center, a research branch of the Department of Electrical and Computer Engineering, on projects related to power electronics/industrial controls, or on manufacturing related projects supported by a grant from Cooper Industries. Applicants must possess a B.S.E.E. and a minimum undergraduate GPA of 3.3/4.0 The stipend is $12,000 for 12 months for M.S. students and $15,000 for 12 months for Ph.D. students, plus tuition waiver. Send a brief resume and transcripts before March 1, 1992 to: Dr. Roger Radcliff, Dept. of Electrical and Computer Engineering, 325 Stocker Center, Ohio University, Athens, OH 45701-2979.

Graduate Fellowships and Research Associates. Fellowships and Associateships are available for M.S. or Ph.D. students in Electrical Engineering. Fellowships provide a nine-month stipend of $15,000 for Ph.D. students and $12,000 for M.S. students plus tuition waiver. The stipend for Research Associates is $8,000 for nine months plus tuition waiver, and requires research duties under the direction of a faculty member. Applicants must be U.S. citizens and possess a B.S.E.E. or M.S.E.E. from an engineering department that has a basic or advanced program that is ABET accredited. Minimum undergraduate GPA's are 3.5/4.0 for a Fellowship and 3.1/4.0 for an Associateship. For consideration, send a brief resume and transcripts before March 1, 1992 to: Dr. Roger Radcliff, Dept. of Electrical and Computer Engineering, 325 Stocker Center, Ohio University, Athens, OH 45701-2979.

University of Virginia Department of Electrical Engineering invites applications for tenure-track positions at the assistant professor level. Responsibilities include teaching at both undergraduate and graduate levels, carrying out of scholarly research, and service to the University and profession. An earned doctorate in electrical engineering, a strong commitment to excellence in undergraduate and graduate teaching, along with willingness and ability to secure sponsored research are required. Well established research programs exist in the department in the areas of computer engineering, solid state electronic and photonic devices, robotics and machine vision, and communications and signal processing. The department's

primary faculty need at this time is in the areas of computer engineering, control theory, and microwave circuits and devices. Interested individuals should send a complete resume, statement of present employment and citizenship (or visa) status together with the names and addresses of at least three references to: Dr. Robert J. Mattauch, Chairman, Department of Electrical Engineering, Thornton Hall, University of Virginia, Charlottesville, VA 22903-2442. The University of Virginia is an Equal Opportunity/Affirmative Action Employer.

Faculty Positions in Electrical and Computer Engineering. GMI Engineering & Management Institute, Flint, Michigan, invites applications for tenure-track faculty positions in the Electrical & Computer Engineering Department. All areas of specialization will be considered; however, preference will be given to candidates prepared to teach electronics, communication systems, controls and signal processing. Candidates are expected to have a major commitment to undergraduate and graduate teaching along with an interest in professional development through research and consulting. Teaching and industrial experience are highly desirable. These positions require a Ph.D. in Electrical or Computer Engineering. GMI operates on a five-year fully cooperative plan of undergraduate education. The college also offers bachelor of science degrees in mechanical, industrial, electrical, and manufacturing systems engineering, and management. Masters degrees are offered in manufacturing management and engineering. GMI strongly supports collaborative research and consulting between faculty and industrial partners. Send resume and names of at least three professional references to: Chairman of Faculty Search Committee, Electrical & Computer Engineering Department, GMI Engineering & Management Institute, 1700 W. Third Avenue, Flint, MI 48504-4898. Preference will be given to applicants with U.S. citizenship or permanent resident status. GMI is an equal opportunity/affirmative action employer and actively seeks the candidacy of women and minorities. Application deadline is February 15, 1992.

Electrical Engineering Faculty Position. Lamar University is seeking a tenure track assistant professor to establish a research program and teach graduate and undergraduate courses in one of the following areas: (1) power systems, electric machines and fields or (2) electronics, communication theory, and instrumentation. An earned doctorate in EE must be completed by date of appointment. For full consideration, applications should be received by March 1, 1992. The position will be open until filled. Please send resume to Prof. F.M. Crum, Chair, Electrical Engineering Dept., Lamar University, P.O. Box 10029, Beaumont, TX 77710. Lamar University—Beaumont is an EO/AA Employer.

Texas Tech University. The Department of Electrical Engineering at Texas Tech University invites applications for tenure track assistant professor positions. Outstanding candidates in all areas of electrical engineering will be considered. Areas of established research programs include pulsed power techniques, optical and digital signal/image processing, neural networks, systems theory, plasma theory and applications, optical computing, computer vision, VLSI design, power semiconductor devices, and power electronics. Applicants must hold a doctoral degree and have a commitment to an integrated educational program involving both undergraduate and graduate teaching and the development of an active research program. Texas Tech has an enrollment of 25,000 students, and is one of the four major comprehensive state universities in Texas. The University is located in Lubbock, a city of 200,000 known for its pleasant weather and hospitality. Applicants should send their resumes and the names, addresses, and phone numbers of three professional references to Chairman, Department of Electrical Engineering, Box 43102, Lubbock, TX 79409-3102. Texas Tech University is an Affirmative Action/Equal Opportunity Employer. Proof of legal right to work in U.S. required.

Solid State Electronics, University of Cincinnati. Applications are invited for a research associate/post-doctoral position in the area of epitaxial growth of compound thin films (GaAs & InP based technologies) using a metal-organic chemical vapor deposition (MOCVD/MOVPE) system. The person will work with an existing group of faculty to design and implement growth processes for quantum well and superlattice structures for microwave, electronic, and photonic devices. He/she will be responsible for the operation of the recently acquired state-of-the-art MOCVD machine and associated materials characterization equipment. Applicants should have a Ph.D. in electrical engineering or physics with experimental orientation and hands-on experience in solid state electronics. Experience with materials characterization techniques and equipment such as x-ray, ESCA, TEM, PL, SIMS, and other microelectronics fabrication is highly desirable. Send resume to Prof. Vik J. Kapoor, Department Head, Department of Electrical and Computer Engineer, University of Cincinnati, Cincinnati, Ohio 45221-0030 (email vkapoor@uceng.uc.edu). The university is an affirmative action, equal opportunity employer.

University of California, San Diego. The Department of Electrical and Computer Engineering is seeking a distinguished individual with an earned Ph.D. degree to fill a position at the Full or Associate Professor level in Machine Intelligence and Robotics. The individual will be expected to provide a leadership role in developing this new program. Applicants must demonstrate expertise in theoretical and system integration aspects of machine intelligence and robotics. Duties will include research and teaching. Salary and rank will be determined by qualifications and UC pay scales. Applications received by March 1, 1992 will be considered. Interested applicants should send a current resume and the names of at least five references to Dr. Manuel Rotenberg, Chairman—University of California, San Diego, Department of ECE—Mail Code 0407, 9500 Gilman Drive, La Jolla, CA 92093-0407. Immigration status of non-citizens should be stated in the dossier. UCSD is an Equal Opportunity Affirmative Action Employer.

University of Pittsburgh. The Department of Electrical Engineering has one or more tenure-track openings for September 1992. Preferred areas are device electronics (fabrication, modeling and characterization of III-V compound electronic or opto-electronic devices), signal processing (spectrum estimation and modeling, multidimensional signal processing) and control (robust, intelligent, adaptive). Applicants should send their resumes, the names of three references and a short description of their research interests to Chair, Search Committee, Department of Electrical Engineering, University of Pittsburgh, Pittsburgh, PA 15261. The University of Pittsburgh is an equal opportunity/affirmative action employer.

Department Chair: Applications are invited for the position of Professor and Chair of the Electrical Engineering Department at Lamar University. Qualifications of applicants must include an earned doctorate in electrical engineering. In addition, teaching experience, scholarly achievements, an on-going research program, and university administrative experience are desirable. Applicants should submit resumes including a list of three references to: Chair EE Select Committee, College of Engineering, Lamar University, P.O. Box 10029, Beaumont, TX 77710. The review of applications will begin March 23, 1992 and will continue until the position is filled. Lamar University is an equal opportunity, affirmative action employer.

University of Colorado at Denver, Faculty Positions. The Department of Electrical Engineering is accepting applications for tenure-track Assistant Professor positions for Fall 1992 in the areas of Digital Design/Computer Engineering and Circuits/Electronics. Candidates must have an earned Ph.D. at the time of employment with an established publication and research record. Industry experience is preferred. CU-Denver is the urban campus of the University of Colorado with both undergraduate and graduate programs as well as strong university-industry relations. Please send resume and the names, addresses, and telephone numbers of at least three references to Dr. Jan T. Bialasiewicz, Chair of the Search Committee, EE Department, University of Colorado at Denver, Campus Box 110 P.O. Box 173364, Denver, Colorado 80217-3364. Applications will be accepted until the positions are filled. The University of Colorado at Denver is committed to enchancing the diversity of its administration, faculty and staff and invites and strongly encourages nominations of and applications from women and members of ethnic minority groups.

The UCLA Department of Mechanical, Aerospace, and Nuclear Engineering invites applications for a faculty position in plasma physics. Candidates will be considered at the Assistant Professor or Full Professor level. Preferably, the department is seeking a distinguished, well established scholar who has done research in the area of theoretical plasma physics with an emphasis on problems important to magnetic fusion research. Experience and interest in the use of advanced computational methods is desirable in order to augment existing strengths at UCLA in computational fluid dynamics and plasma simulations. The candidate should be highly motivated to enhance our graduate research program in fusion, to interact with other faculty and staff in the department and in the Institute of Plasma and Fusion Research at UCLA, and to interact with individuals at government research center and industry who are at the forefront of fusion plasma physics research. It is expected that the candidate would establish and lead a major research activity. Salary and appointment level will be commensurate with experience and qualifications. Candidates should submit a letter of application, a complete resume, and the names of five references to: Prof. Robert W. Conn, Chairman of Search Committee, Department of Mechanical, Aerospace and Nuclear Engineering, 44-139 Engineering IV, 405 Hilgard Avenue, University of California, Los Angeles, Los Angeles, CA 90024-1597.

Boston University Chair, Department of Biomedical Engineering. Boston University's College of Engineering invites applications and nominations for the position of Chairperson, Department of Biomedical Engineering. The Department currently has two associated centers (the NeuroMuscular Research Center and the Center for Molecular Engineering), 18 full time faculty with annual sponsored research exceeding $2 million dollars, 81 graduate students and 130 upperclass undergraduates. We seek a distinguished engineer/scientist with a proven research record to lead the Department in its continuing growth. The University has invested 110 million dollars in new facilities for engineering and science over the last five years and has recently made major commitments to the further growth of the College in conjunction with the appointment of a new Dean of Engineering. The Department maintains a central position within the College due, in part, to the diverse backgrounds and research areas of its faculty. The Chair will be expected to provide leadership in the continuing development of graduate teaching and research, and to strengthen collaborations with the basic science departments, the Sargent College of Allied Health Professions, the Boston University Medical School and other area hospitals and companies. A letter of interest or nomination, curriculum vitae, and the names of at least three references should be sent to Allyn Hubbard, Ph.D., Biomedical Engineering Search Committee, Boston University, 44 Cummington Street, Boston, MA 02215. An equal opportunity, affirmative action employer.

University of California at Berkeley Faculty Positions in Simulation and Visualization, Electronic and Optoelectronic Devices and Technology, and Low-Temperature Electronics, beginning in Fall Semester 1992, pending budgetary approval. The Department of Electrical Engineering and Computer Sciences at the University of California at Berkeley is currently seeking outstanding faculty candidates with research in the general areas of: (i) Simulation and Visualization. Areas of interest include the use of computers to simulate complex

phenomena, devices, and systems, and to the presentation of these calculations in visual form to promote understanding. The candidate must emphasize the use of simulation and visualization in at least one of the following application areas: a. the reconstruction of multidimensional configurations (3D or higher) from lower dimensional data as in tomography, NMR and NRI imaging, and in seismic data b. the analysis, understanding, and design of complex control or communication systems c. the analysis and design of electronic or mechatronic devices d. the modeling of complex physical phenomena, including plasmas, semiconductor processing equipment and semiconductor devices. The candidate should be able to teach basic courses in systems, communications and control. Appointment will be made only at the Assistant Professor level in a tenure-track position. (ii) Electronic and Optoelectronic Devices and Technology. Areas of interest include electronic/optoelectronic devices based on nanostructures and/or ultrafast phenomena. Candidates should have a strong record of research and are expected, along with other members of the faculty in this and other departments (material science and physics) as well as scientists at Lawrence Berkeley Laboratory, to provide leadership in this field of research. Although technology and fabrication aspects are considered an essential part of nanostructure/high speed device research, preference will be given to research in the actual creation of novel devices/new functions and device physics studies. The potential to initiate collaborative efforts involving advanced facilities, such as Advanced Light Source (Synchrotron radiation) at Lawrence Berkeley Laboratory, will be positively (although by no means exclusively) considered. The candidate should be able to teach basic courses in electronic devices and/or optoelectronics. It is expected that the appointment will be made at a senior, tenured level, although applications will also be considered for a junior level appointment. (iii) Superconductive Electronics/Electromagnetics. Candidates might have interests in superconducting digital circuit design and/or device and fabrication technology for low and high-temperature superconductors. Candidates from related fields such as electromagnetics will also be considered. Candidates will be expected to teach undergraduate and graduate courses in semiconducting or superconducting devices, technology, circuits, physical electronics, or electromagnetics. The appointment will be made at the Assistant Professor level only in a tenure-track position. Applicants must have a doctoral degree or comparable academic and industrial experience. Interested persons should apply as soon as possible and by February 28, 1992 to insure full consideration, to the Chairman, at the address listed below, including a resume, copies of publications, a statement of interest, and names and addresses of references. Professor Paul Gray, Chairman, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, California 94720. Telephone (510) 642-0253. The University of California is an Equal Opportunity, Affirmative Action Employer.

Post-Doctoral Position, Neural Networks. Texas A&M University. A postdoc is sought for basic and applied neural networks research, with emphasis in system identification, forecasting and signal processing in energy systems. Salary negotiable. Texas A&M University is an Equal Opprt./Affirmative Action Employer. Send c.v., 3 referee names and copies of recent papers and/or dissertation to: Dr. Alexander G. Parlos, Texas A&M University, MS 3133, College Station, TX 77843.

The Department of Electrical Engineering at the University of Maine invites applications at all ranks for a tenure track position in computer engineering beginning September 1992. Areas of particular interest are computer systems, robotics, machine vision and neural networks. Applicants should have an earned doctorate. The successful candidate will be expected to contribute to undergraduate and graduate teaching and to establish a research program. Salaries are competitive and arrangements are made to assist junior faculty in initiating a research program. Applicants must send a resume which clearly indicates citizenship/visa status, a statement concerning teaching and research interests and a list of three references to: EE Search Committee, Barrows Hall, University of Maine, Orono, ME 04469. Applications from women and minorities are particularly encouraged. Review of applications will begin immediately. The University of Maine is an Equal Opportunity/Affirmative Action Employer.

Biomedical Engineering—Tulane University: Two positions are expected to be available beginning Fall, 1992. Both are tenure-track full-time appointments in the Tulane University School of Engineering, with rank and salary dependent on the candidate's qualifications. Applicants are sought with expertise in the following areas: (1) polymeric biomaterials and biomedical materials science, and (2) instrumentation, medical imaging or biomedical signal processing. Send CV and names of references by March 1, 1992 to: Dr. Richard T. Hart, Dep't. of Biomedical Engineering, Tulane University, New Orleans, LA 70118. Tulane University is an Equal Opportunity/Affirmative Action employer.

Oklahoma State University Computer Science Department. Applications are invited for full-time tenure track positions at the Assistant Professor level. The term of initial appointment will begin in Fall 1992. The Oklahoma State University Computer Science Department is seeking applications from qualified individuals in all areas of Computer Science. However, it is interested especially in candidates with research experience in the programming languages or artificial intelligence areas. A Ph.D. in Computer Science is required. The department currently has 10 full-time faculty members and is committed strongly to the goal of research excellence. The new faculty members will have the opportunity to influence the growth and direction of a growing department. The department offers a full range of undergraduate and graduate courses. There are currently over 130 graduate students, of whom approximately 20 are Ph.D. students. The faculty members will have access to a variety of departmental, inter-departmental, and University Computer Center machines. The list includes IBM 3090, Hypercube, and Sun SPARC stations. Stillwater is a small, attractive university city of about 38,000 people, located on the prairie in north-central Oklahoma. Stillwater is 65 miles West of Tulsa and 65 miles North of Oklahoma City. There are numerous cultural activities to be found within a two-hour drive of Stillwater. The Oklahoma State University campus is one of exceptional beauty, with modified Georgian architecture in all buildings. Oklahoma State University encourages applications from qualified women, minorities, and persons with disabilities. Please send curriculum vita and names of three references by March 1, 1992 to: K.M. George, Chair, Faculty Search Committee, Computer Science Department, Oklahoma State University, Stillwater, OK 74078-0599. E-mail:kmg@a.cs.okstate.edu, phone: (405) 744-5668. FAX: (405) 744-7074. The closing date is March 1, 1992 but applications will be considered until the positions are filled. Oklahoma State University is an Affirmative Action/Equal Opportunity Employer.

University of Rochester, Electrical Engineering. Research Associate: involved in research leading to the development of optoelectronic materials and devices, and in the supervision of graduate student's research. Duties include designing and building ultrafast laser systems and designing, processing and testing structures and devices. Must be familiar with femtosecond laser spectroscopy, semiconductor processing, and electronics. A Doctorate in Electrical Engineering is required. Candidates must have established research ability in the physics of laser-semiconductor interactions as evidenced by refereed publications. Starting annual salary of $29,000 plus benefits. Applicants should send a full resume and copies of relevant publications to: Professor Edwin Kinnen, Chair, Dept. of Electrical Engineering, University of Rochester, 517 Computer Studies Bldg., Rochester, NY 14627. The University of Rochester is an Equal Opportunity Employer (M/F) and specifically invites and encourages women and minorities to apply.

Wayne State University has two openings for tenure-track faculty in the Electrical and Computer Engineering Department. We are seeking research oriented individuals interested in computer engineering, with emphasis on any of the following: networks, parallel and distributed processing, modeling and performance analysis or VLSI design. Applicants should have an earned Ph.D. and be committed to teaching and research. Rank and salary will depend on experience and qualifications. Wayne State is a large urban university, and welcomes applications from women and minorities. Resumes should be sent to Dr. M.P. Polis, Chair, ECE Dept., Wayne State University, Detroit, MI 48202. Wayne State University is an Equal Opportunity/Affirmative Action employer.

Engineering Technology Department Chair, responsible for TAC/ABET accredited programs in Electronics, Civil, and Mechanical Engineering Technology. Masters degree in engineering, engineering technology, or related area required. Doctorate and suitable administrative experience desirable. Teaching experience and three years related industrial experience required. Must be able to teach in several of the following areas: circuits, analog electronics, digital electronics, communications, control systems; and work in a multi-cultural academic community. Citizenship or permanent resident status required. Tenure track. Open until filled. Screening begins February 15, 1992. Send letter of application, resume, unofficial transcripts and the names, titles, addresses, and phone numbers of three references to: Prof. David Perkins, Chair, Engineering Technology, University of Southern Colorado, Pueblo, CO 81001-4901. USC is an AA/EO Employer.

The Electrical Engineering Department at the University of North Carolina at Charlotte invites applications for two tenure-track positions at the Assistant, Associate, or Full Professor level. Areas of interest include, a) integrated circuit processing and instrumentation, b) optical devices and systems. Positions begin Fall of 1992. The University of North Carolina at Charlotte is one of the largest institutions of the UNC system with over 15,000 students, including 2,125 graduate students in the six colleges. The department is one of five in the College of Engineering and currently enrolls 365 students, of which 60 are graduate students and Postdoctoral Research Associates. Computer facilities include micros, minis, workstations and free access to Cray YMP supercomputer. The laboratory facilities include a class 100 clean room with complete integrated circuit and microstructure fabrication capabilities, laboratories for measuring the electrical properties of the insulator-semiconductor surface, computerized IC test facilities, laser electro-optic laboratory, dry processing laboratory for VLSI fabrication, and MBE laboratory for quantum well superlattice and optoelectronic materials. As a participating institution of MCNC (Microelectronics Center of North Carolina), the faculty have access to the MCNC facilities with capabilities of submicron IC design, fabrication, test, and semiconductor materials analysis. Charlotte is the largest city in the Carolinas and offers good schools and attractive housing. The 100,000 sq. ft. engineering building and a 75,000 sq. ft. Applied Research Center are located adjacent to the 2,800 acre University Research Park. Various forms of career development support are available. Applicants should have a Ph.D. degree or equivalent and have commitment to teaching and pursuing research. Industrial and research experience is desirable. Rank and salary commensurate with experience. Applications will be accepted until March 1, 1992. Initial screening begins February 1, 1992. Applications, including a resume and a list of four references, should be sent to: Dr. F.M. Tranjan, Chairman, Search Committee, Electrical Engineering Department, UNC-Charlotte, Charlotte, NC 28223. UNC-Charlotte is an equal opportunity affirmative action employer, and complies fully with the Immigration Reform and Control Act of 1986.

Research Associate/Research Assistant Professor, Magnetic Field Measurement and Modeling. The Living State Physics Group and the Electromagnetics Laboratory of the Department of Physics and Astronomy at Vanderbilt University have active research programs utilizing SQUID magnetometers for both biomagnetic studies and non-destructive evaluation (NDE). We are seeking a Ph.D. physicist or en-

gineer with experience in magnetic field measurement and modeling, and apparatus design and construction. Experience in electronics, data acquisition systems, computer programming, and image processing preferred. Salary and rank will be based upon experience and other qualifications. Starting date negotiable. Send curriculum vitae, representative publications, and names and addresses of three references to Dr. John P. Wikswo, A.B. Learned Professor of Living State Physics, Department of Physics and Astronomy, Vanderbilt University, P.O. Box 1807, Station B, Nashville, TN 37235. Vanderbilt University is an equal employment opportunity/affirmative action employer.

Research Scientist in Superconductor Electronics—The State University of New York at Stony Brook invites applications for a Research Scientist position in the field of superconductor electronics. Responsibilities include experimental studies of superfast Single-Flux-Quantum digital devices and circuits, development of related experimental facilities, participation in circuit fabrication, and guidance of student research, in a collaboration with the SFQ circuit design group. Required qualifications include a Ph.D. in electronic engineering or physics and relevant research experience. The position will be for three years, with a possible extension. Salary will be competitive, commensurate with qualifications. Applicants should send a C.V. and the names of three references to: Professor Konstantin K. Likharev, Department of Physics, SUNY at Stony Brook, Stony Brook, NY 11794-3800, by February 1, 1992. SUNY at Stony Brook is an affirmative action/equal opportunity educator and employer. Minorities and women are encouraged to apply. AK115.

Research Scientist in Fabrication of Cryogenic Integrated Circuits: Stony Brook University—Funding is anticipated for a research staff position focused on the fabrication of analog and digital circuits using niobium Josephson junction technology. We invite applications for this position from persons having a Ph.D. in Physics, Materials Science or EE along with a record of significant achievement in integrated circuit fabrication at the micron and submicron level. Experience in the fabrication of integrated circuits using superconducting materials is highly desirable. The responsibilities of this position will include adaptation and refinement of our existing Nb/A10x/Nb fabrication technology for use in LSI digital and analog circuits. The person selected for this position will be involved in fabrication of circuits designed by the existing research groups of Professors Konstantin Likharev and James Lukens as well as in the training and supervision in circuit fabrication of staff and Ph.D. students in these groups. This person will be expected to be proficient and assist in the development, troubleshooting and maintenance of all equipment used in the thin film processing and in addition to be familiar with similar work at other laboratories and in journals, and to present results of work at Stony Brook at professional meetings and in journal publications. Applicants should send a C.V. and names of three references to: Professor James Lukens, Department of Physics, SUNY at Stony Brook, Stony Brook, NY 11794-3800 by February 15, 1992. SUNY at Stony Brook is an affirmative action/equal opportunity educator and employer. Minorities and women are encouraged to apply. AK116

The Department of Bioengineering, University of Utah, has openings for two tenure-track Ph.D. assistant professors in the areas of tissue and molecular/nano engineering and neurophysiological modeling. Applicants should have strong physical science or engineering background with experience and interest in cell and tissue culture; hybrid artificial organs; cell, tissue, and molecular assembly and patterning; or neuro-electric phenomenon. Complete CV, names of three references, and brief career goals/objectives statement should be sent to Dr. R. Normann, Acting Chair, Department of Bioengineering, 2480 MEB, University of Utah, Salt Lake City, UT 84112, (801) 581-8528, FAX (801) 581-8692, by February 15, 1992, or until the positions are filled. The University of Utah is an Equal Opportunity/Affirmative Action employer, and women and minorities are encouraged to apply.

The Ohio State University, Department of Electrical Engineering, invites applications for a tenure-track faculty position in Communications. Applicants must have a Ph.D. degree in Electrical Engineering or a related field, outstanding academic credentials, potential for developing research programs, and an interest in teaching at the undergraduate and graduate levels. Send resume and the names of references to: R.E. Fenton, Chairman, Personnel Committee, Department of Electrical Engineering, The Ohio State University, 2015 Neil Avenue, Columbus, OH 43210. The Ohio State University is an equal opportunity/affirmative action employer.

University of Central Florida (UCF); The Electrical Engineering Department (32 faculty, 720 undergraduates, 280 graduate students) anticipates tenure-track openings in Communications, Controls, Digital Signal Processing, and Microelectronics, starting in the Fall of 1992. Rank and salary will be commensurate with qualifications. All applicants must have a Ph.D. at the time of employment and a strong commitment to teaching and research. Applications must be post-marked no later than February 14, 1992 and must be sent to: Dr. N.S. Tzannes, Chair, Electrical Engineering, University of Central Florida, Orlando, Florida 32816. UCF is an equal opportunity/affirmative action employer. As an agency of the State of Florida, all application materials and selection procedures are available for public review.

Electrical Engineering Technology. One or two tenure-track positions at Assistant Professor level in TAC/ABET accredited baccalaureate program beginning in August 1992 (subject to later budget approval). Minimum requirements are a master's degree in electrical engineering, electrical engineering technology, or an equally relevant professional field and three years minimum industrial experience. Professional registration strongly encouraged. Exact specialty areas depend on whether one or two positions are funded, but all EET faculty are expected to teach in at least two of the following areas (both lecture and laboratory): electrical power and machinery, automatic controls, circuits, linear electronics, digital electronics, (including microprocessors), computer-aided design. Participation in industry sponsored projects through the Technology Application Center is encouraged. Closing date for applications is March 1, 1992. Send application and names of three references to Program Director, Electrical Engineering Technology, Old Dominion University, Norfolk, Virginia 23529-0243. Applications from minorities and women are encouraged. Old Dominion University is an affirmative action, equal opportunity institution and requires compliance with the Immigration Reform and Control Act of 1986.

The Center for Advanced Computer Studies. The Center is seeking qualified candidates for a tenure track faculty position in Computer Science and Computer Engineering at the Professor rank beginning Fall 1992. Candidates must hold PhDs in the field, and have established research publications and grant records. Candidates for Assistant Professor will also be considered. They must hold PhDs in the field, and must have strong research potential. Consideration will be given to all qualified candidates, but preference areas of interest are: software engineering, computer networks, operating systems, databases, computer architecture, artificial intelligence, and theoretical computer science. The Center conducts programs leading to the MS/PhD degrees in Computer Science and Computer Engineering. These programs currently enroll more than 220 students, including over 100 PhD students. A number of PhD fellowships and assistantships are available, with stipends of up to $18,000 per year, renewable for a maximum of 4 years. Typical faculty teaching load is 2 courses per year and a continuing research seminar. Substantial State Educational Fund monies are available to establish research programs. The University is located in Acadiana, a short distance west of New Orleans. Send resumes to: Dr. Michael C. Mulder, Director, The Center for Advanced Computer Studies, University of SW Louisiana, P.O. Box 44330, Lafayette, LA 70504. Review of applications will begin February 1992. The University of SW Louisiana is an affirmative action/equal opportunity employer.

Undergraduate Summer Institutes on Contemporary Topics in Applied Science—June 8-19 or Aug. 17-28, 1992. Held since 1985, the Institutes are sponsored by the UC Dept. of Applied Science (DAS) at Livermore, by the Fannie & John Hertz Foundation, and by Lawrence Livermore National Laboratory. Approx. 30 students will be selected for each session to attend lectures and carry out research projects under the guidance of LLNL scientists and DAS faculty members. Travel/living expenses will be paid and a grant from the Hertz Foundation will allow $500 stipend to each participant. Open to full-time students in a recognized undergraduate Physics, Chem., Materials Science, or Eng. program who will have senior status by fall, 1992. Selection will be made on the basis of the applicants academic record, aptitude, research interests, and written recommendations of instructors. For further information/application, write or phone: Summer Institutes, DAS, UC-Davis/Livermore, P.O. Box 808, L-725, Livermore, CA 94551. (510) 423-9756. Completed application due by Jan. 17, 1992. U.S. Citizenship required. EOE.

Department Chair, Electrical Engineering—The University of Colorado at Denver invites applications for the position of Chair, Department of Electrical Engineering. This position requires an earned doctorate in electrical engineering with a record of distinction in university teaching, publications, and research worthy of a tenured full professor. Industrial and administrative experience is preferred. The Electrical Engineering Program is accredited by ABET at the bachelors level and offers B.S., M.S. degrees and an integrated Ph.D. program coordinated with the University of Colorado at Boulder. It has 13 faculty positions and a present enrollment of 280 undergraduates and 96 graduate students. The University of Colorado at Denver is an urban campus that serves both full-time and part-time students. Interested applicants should send their resume (with at least three references—include addresses and phone numbers) to Professor Jan T. Bialasiewicz, Search Committee Chairperson, Electrical Engineering Department, University of Colorado at Denver, P.O. Box 173364, Denver, Colorado 80217-3364. Applications will be accepted until March 15, 1992, or until a suitable candidate has been selected. The University of Colorado at Denver is committed to enhancing the diversity of its administration, faculty and staff and invites and strongly encourages nominations of and applications from women and members of ethnic minority groups.

California State University, Fresno—Electrical and Computer Engineering Department is seeking applicants for a position beginning in August 1992. An earned Ph.D. and B.S. Degree in Electrical or Computer Engineering are required for appointment at all professorial ranks for lecturer, depending on qualifications. The successful candidate may be expected to teach courses, develop curricula and laboratories in accordance with his/her expertise in one of the following areas: 1) Electro-magnetics, microwave engineering and/or physical electronics and IC design/fabrication, 2) Design of digital systems and computers, computer architecture, artificial intelligence, and image processing. Candidates with teaching and industrial experience will be given preference. U.S. Citizenship or permanent residence is required. Send applications to: Chairman, Dept of Electrical and Computer Engineering, California State University, Fresno, CA 93740-0094, tel. (209) 278-2726. Electrical and Computer Engineering is a strong, high quality program at CSU Fresno with approximately 450 students currently enrolled. The department enjoys an excellent reputation throughout the high-tech industries of California and the West, and with prestigious graduate schools who recruit our graduates.

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Rensselaer Polytechnic Institute, Director, Center for Manufacturing Productivity and Technology Transfer. The School of Engineering at Rensselaer Polytechnic Institute is seeking an outstanding individual to lead the Center for Manufacturing Productivity and Technology Transfer (CMPTT). The CMPTT, founded in 1979, is an interdisciplinary research center within the School of Engineering and a focal point for major research initiatives in manufacturing at Rensselaer. The Director of the CMPTT reports to the Dean of Engineering and occupies a position of research and academic leadership within the School. With over six million dollars in annual research expenditures, participation from over 25 academic faculty, and 34 full-time staff including project managers, research engineers, technicians and support personnel, the CMPTT has established an international reputation for its contributions to manufacturing research and successful interactions with industry. The technical programs of the CMPTT include: Advanced Materials: Processing, Evaluation, and Recovery, Electronics Manufacturing, Computer-Integrated Manufacturing, Manufacturing Control, Sensors and Inspection, and Product/Process Design and Support Systems. The Northeast Manufacturing Technology Center, a National Institute of Standards and Technology program, is managed within the CMPTT and focuses on technology transfer activities. The CMPTT occupies a major portion of a recently constructed research building and maintains extensive laboratory and computing facilities. The successful candidate for this position should have a strong record of academic and/or industrial research in manufacturing, as well as a background and demonstrated capability in strategic planning, innovative program development and management of interdisciplinary teams. Candidates with experience and qualifications appropriate to a tenure-track appointment in one of the academic departments of the School of Engineering are especially encouraged to apply. Please send applications and nominations to: Professor Arthur C. Sanderson, Chair, Search Committee, Electrical, Computer, and Systems Engineering Department, Rensselaer Polytechnic Institute, Troy, New York 12180-3590. Applications should include a resume, a summary of research and managerial experience, and the names of at least three references. Rensselaer Polytechnic Institute is an equal opportunity/affirmative action employer.

Princeton University: The Department of Electrical Engineering invites applications for a full time research post doctoral position in the area of image/video processing and transmission. One of the responsibilities will be to supervise a state-of-the-art Image processing laboratory which includes a DVS image sequence storage system with HDTV codec, an HDTV display, a laser disk image sequence recorder and 24-bit workstations. Please send a complete resume, a description of research interests and experience and the names of three references to Professor Stuart Schwartz, Chairman, Dept. of EE, Princeton University, Princeton, NJ 08544. Princeton University is an equal opportunity/affirmative action.

Faculty Positions—The Computer Science Department of the University of Maryland, College Park (UMCP), seeks first-rate faculty members at all ranks. The Department is located in suburban Washington, D.C., in close proximity to many large governmental and industrial laboratories and within easy access of Baltimore and Annapolis. It has close to 45 faculty members, and maintains strong degree programs at both the undergraduate and graduate levels. Major research projects in areas such as artificial intelligence, computer vision, database systems, distributed systems, human-computer interaction, numerical analysis, parallel processing, performance evaluation, software engineering, theory and analysis of algorithms are funded at an annual level of about $5M. Exceptionally strong candidates may be considered for appointment in the University of Maryland Institute for Advanced Computer Studies (UMIACS) or the Center for Excellence in Space Data and Information Sciences (CESDIS) located at the NASA Goddard Space Flight Center. Candidates should send a curriculum vitae, a research summary, and names of at least three references to the Recruiting Committee, c/o Professor Satish K. Tripathi, Chair, Department of Computer Science, University of Maryland, College Park, MD 20742. For full consideration, applications must be received by February 1, 1992. The University of Maryland is an equal opportunity, affirmative action employer.

Massachusetts Institute of Technology, Sloan School of Management. Faculty Position in Operations Management. The Operations Management group at the MIT Sloan School of Management invites applications for a tenure-track faculty position. The Sloan Operations Management group has diverse interests and expertise, ranging from operations modeling and decision support to contemporary issues in design-manufacturing integration, computer-integrated manufacturing, system dynamics, management of technology and total quality management. We welcome specialists in any engineering or management field related to manufacturing or service operations. The MIT Sloan School offers attractive opportunities for interdisciplinary research collaboration and contact with industry. Operations management faculty participate actively in MITs Leaders for Manufacturing program and several other institute-wide cross-functional research programs and centers. The operations management group offers a variety of graduate courses, and is also involved in undergraduate and executive education. Please send a current resume, an extended dissertation abstract, copies of any publications, and have letters of recommendation sent by January 31, 1992 to: Professor Anant Balakrishnan, MIT Sloan School of Management, 30 Wadsworth Street, Room E53-340, Cambridge, MA 02139. MIT is an affirmative action and equal opportunity employer. We strongly encourage applications from qualified women and minority candidates.

Research Engineer—The MIT Plasma Fusion Center is seeking a Research Engineer to work in the Fusion Technology and Engineering Division on problems associated with cryogenic and superconducting magnet system design and construction for special applications. Individual will interface with senior staff on analyses, design, model development, experimental program definition and execution. Salary range: $59,000 to $74,000. Ph.D. in Mechanical or Electrical Engineering plus at least four years experience in electromechanical analysis. Specific experience in one or more of the following areas is required: 1) magnetoelasticity of thin shells; 2) eddy current nondestructive testing techniques and analysis; and 3) magnetic levitation problems. Interested persons should submit their resume and cover letter (only) referencing position #PFC/IEEE-R9124 to: Prof. Ronald R. Parker, Director, Plasma Fusion Center, 167 Albany Street, Room NW16-288, Cambridge, MA 02139. MIT is an Equal Opportunity/Affirmative Action Employer. MIT is a non-smoking environment.

Old Dominion University. The Department of Electrical and Computer Engineering invites applications for anticipated tenure-track faculty positions in computer engineering beginning August 1992. An earned doctorate in electrical or computer engineering is required. Duties include undergraduate and graduate teaching and development of a strong research program. Rank and salary commensurate with qualifications. For full consideration, submit letter of application, resume, statement of citizenship or visa status, and list of three references by March 1, 1992 to: Professor R.R. Mielke, Chairman, Department of Electrical and Computer Engineering, Old Dominion University, Norfolk, VA 23529-0246. Old Dominion University is an affirmative action/equal opportunity employer and requires compliance with the Immigration Reform and Control Act of 1986.

The University of Calgary Chair in Wireless Communications—The University of Calgary Department of Electrical and Computer Engineering invites applications for an industry-supported Chair in Wireless Communications. This is a tenure-track position and involves a half teaching load with major research work to be done in conjunction with the Telecommunications Research Laboratories (TRLabs). TRLabs is a research consortium involving The University of Calgary, the University of Alberta, AGT Limited, Bell Northern Research, LSI Logic, Digital Equipment Corporation, Edmonton Telephones and NovAtel. Chair candidates should have a proven track record in leadership, teaching and research in wireless communications. Disciplines of particular interest are channel characterization, simulation and modelling; r.f. device, circuit and subsystem design; modulation, coding and equalization; and wireless sytems access, traffic, architectures and protocols. Specialization in signal processing is also of key interest. The successful candidate will be expected to build a research team and a strong program in wireless communications. The University of Calgary Department of Electrical and Computer Engineering currently has eight professors in these and closely related fields. The establishment of this Chair is contingent on approval of complementary financial assistance from the Natural Sciences and Engineering Research Council (NSERC). In accordance with Canadian Immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada, but other qualified candidates are encouraged to apply. The University of Calgary has an Employment Equity Program and encourages applications from all qualified candidates, including women, aboriginal people, visible minorities, and people with disabilities. The University offers a Dual Career Assistance Program for spouses. Applicants should send a curriculum vitae, a statement concerning teaching and research interests and a list of three references to: Head, Department of Electrical and Computer Engineering, The University of Calgary, 2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4.

University of Kansas-Electrical and Computer Engineering. A tenure-track faculty opening at the Full or Associate Professor level may be available beginning August 1992 or as negotiated. Rank and salary will be commensurate with qualifications. A doctorate is required. Applicants are sought with teaching and research interest in all areas of computer engineering. New faculty will be expected to perform teaching and curriculum development, to conduct research, and to provide leadership in the area of computer engineering. Preference will be given to applicants with a strong research record and/or industry experience, and whose research interests are consistent with ongoing activities within the Department, especially in software engineering, VLSI design, computer architectures, and artificial intelligence. Review of applications will begin on December 15, 1991 and continue until the position is filled. Send resumes to Dr. Costas Tsatsoulis, Chairman of the Faculty Search Committee, Department of Electrical and Computer Engineering, The University of Kansas, Lawrence, Kansas 66045. Telephone: (913) 864-7749. E-mail: tsatsoul%turing@kuhub.cc.ukans.edu. The University of Kansas is an equal opportunity/affirmative action employer.

Faculty Positions—University of Notre Dame. The Department of Computer Science and Engineering at the University of Notre Dame invites applications for tenure track faculty positions at all ranks. Applicants should have a doctorate in Computer Science, Computer Engineering, Electrical Engineering, or a related field. Candidates in all research areas are invited to apply. However, areas of particular interest within the Department are Parallel and Distributed Computing, Parallel Architectures, and VLSI. Applicants should have abilities and interests in teaching at the undergraduate and graduate levels, advising students, and conducting research. Rank and salary are negotiable. Interested persons should forward a complete resume, together with the names, addresses, and telephone numbers of at least three references, to: Dr. Steven C. Bass, Chairman, Department of Computer Science and Engineering, University of Notre Dame, Notre Dame, IN 46556. The University of Notre Dame is an Affirmative Action/Equal Opportunity Employer.

CLASSIFIED EMPLOYMENT OPPORTUNITIES

Government/Industry Position Open

Design Engineer for firm in NE Ohio. Design and development of Application Specified Integrated Circuits for hand-held computers. In particular, this will involve designing a gate-array based ASIC chip for a new video controller display system for showing computer data on the CRT and/or LCD screen. Must have M.S. (ABT) in Electrical Engineering and must be conversant (as evidenced by either employer testimonials and/or academic letters of reference and/or publications) with the following areas: Random Signal Analysis, Microprocessor Interfaces, VLSI Circuits, Data Communication Systems, Advanced Micro-Computer Systems, and Integrated Circuit Devices. Must have had 2 years exp as design engineer and experience (which may have been gained before, during, or after degree) must have been in designing and developing ASIC circuits for CRT video controllers. 40 hrs/wk, 8am-5pm, $36,600/yr. Must have proof of legal authority to work permanently in U.S. Send resume and course transcript in duplicate (no calls) to S. Holton, JO# 1268867, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

Research Scientist: Analyze & design Acoustic Doppler Current Profilers & related customer application systems. Conduct experiments & computer simulations. Perform error analysis & write technical reports. Develop new innovative products requiring both theoretical analysis & engineering judgement in determining practical solutions. Design & theoretical analysis of Phased Array Doppler Current Profiler. Must have knowledge of advanced mathematics & physics. Must be familiar with the working principles of various kinds of Acoustic Doppler Current Profilers. Must have understanding of various theories & methods used in analog & digital signal processing & dynamic system analysis & synthesis. Must have experience in electronic circuit design & computer programming with various high & low level computer languages. Ph.D. in electrical engineering & 3 yrs experience in job offered required. Job & interview site: San Diego, CA. Salary: $45,000/yr. 40 hrs/wk. Send this ad & your resume to Job # PM10501, P.O. Box 9560, Sacramento, CA 95823-0560 no later than 1/31/92.

Industrial Applications Development Engineer for NE Ohio design & manufacture of industrial equipment firm to develop & engineer new electro-mechanical adhesive application systems for the automotive original & aftermarket equipment market & provide technical electrical engineering marketing support & advice for domestic (U.S.) & international operations. No exp. req. in above job duties, but applicants must have at least 3 mos. exp. as an Electrical Engineer (exp. must be with the design, manufacture, sale & service of microprocessor-based material/fluid dispensing systems). Masters degree in International Business, Marketing, or Trade req. M-F 8AM-5PM. $34,000/yr. Must have proof of legal authority to work permanently in the U.S. Send resume in duplicate (No Calls) to S. Holton, JO#1299674, Ohio Bureau of Employment Services, PO Box 1618, Columbus, Ohio 43216.

Development Staff Member: Performs independent research to improve & develop magnetic head for magnetic disk drives. Utilizes new magnetic characterization methods for magnetoresistive recording heads. Req's: PhD in Electrical Engineering; demonstrated abil. to deduce design criteria for magnetic data heads starting from fundamental micromagnetic principles; demonstrated expertise in characterization & modeling of magnetic thin films, modeling & numerical simulation of magnetic systems; experimental background in VSM, FMR, Torque Magnetometry, Magnetic Domain Observation Techniques; theoretical background in: micromagnetic modeling; statics & dynamics of magnetic domains & domain walls; magnetic reversal processes in magnetic thin films; numerical methods. Above demonstrated by research, dissertation & publications. 40 hrs/wk.; $59K/yr. Job & interview site: San Jose, CA. Send this ad & your resume to Job #LQ 6374, P.O. Box 9560, Sacramento, CA 95823-0560 not later than January 30, 1992. EOE.

Design Engineer for design & mftr in central Ohio area wanted. Duties: Designing industrial control systems & custom engineered control systems using advanced automatic control theory & mathematics, including digital computer control, optimal control, robust stability, & advanced complex & real analysis. Designing microprocessor-based control systems, communication systems, & other electronic equipment. Designing real-time software in C language, Z80 assembly, Intel assembly & Motorola assembly language. Designing hardware of Z80 family & Boolean processor. Designing & developing software for statistical analysis. Requirements: PhD in Electrical Engineering majoring in automatic control theory, or Master's in Electrical Engineering & 3 yrs. exp. as Research Assistant in Electrical Engineering or Electrical Engineer. PhD thesis research (or 3 yrs. exp.) in computer aided industrial control system design & analysis using advanced automatic control theory including digital computer control, optimal control & robust stability & advanced complex & real analysis. Must also have 1 univ. course (or 1 yr. exp.) involving each of the following: microprocessor-based hardware & software design, programmable controllers, statistics, probability theory, designing communication systems, designing Z80 hardware, Boolean algebra, designing real time software using C language & each of the following assembly languages: Z80 & Intel & Motorola. Pay is $36,575 per yr., 40 hr/wk, 8:30am-5:00pm, Mon-Fri. Must have proof of legal authority to work permanently in U.S. Send resume in duplicate (no calls) to S. Holton, JO # 1257424, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216. Employer Paid Ad.

Research Asst. Professor, $25,000/yr, 40 hrs/wk. Will perform research on chemical vapor deposition and etching projects in the Center for Micro-Engineered Ceramics and Chemical & Nuclear Engineering Dept. Will use ultrahigh vacuum equipment, Auger electron spectroscopy and mass spectroscopy, FTIR and Raman spectroscopies. Will also use various lasers and plasma reactors for etching and material deposition of copper and PLZT films. Must have a Ph.D. in Microelectronics or equivalent with background in chemistry, and 3 yrs' experience in laser induced physical, chemical processing. Submit resume to the NM Dept. of Labor, 501 Mountain NE, Albuquerque, NM 87102. CC#1001. JO#334037.

Director of Research and Development. Directs and coordinates activities in research and development of new concepts in computer hardware and software using transformable keyboard and voice recognition control in Japanese for Japanese users in the United States and Far East. Develops and implements methods and procedures for monitoring project. Ph.D. degree in Electronic Engineering and 5 years experience required. Must be fluent in speaking and writing Japanese. $5,000.00 per month; Job site/Interview: Anaheim; Work Hours: 9:00 am to 5:00 pm. Send this ad and a resume to Job #PM 10524, P.O. Box 9560, Sacramento, California 95823-0560, no later than January 31, 1992.

Project Development Engineer—Design & develop advanced electronic assemblies & computers for sensors & control systems for automotive & appliance industries. In charge of technical liason with production sources & project co-developers in Korea & other pacific rim countries. Req'd: B.S. Electronic Engg. 3 yrs exp in position offered or 3 yrs exp as Technical Advisor. Must speak, read, write Korean. 40 hrs/wk; 9 a.m.—5 p.m.; $40,000/yr. Send resumes to: 7310 Woodward Ave., Rm 415, Detroit, MI 48202, Ref. No. 94591. Employer pd. ad.

Engineer: Senior Process—Cndct basc rsrch for indpndt intrnl/gvnmtl prjcts. Knldg of smcdctr prcsses, dvce physics, & crct systms. Abl to prfrm orgnl rsrch. Knldg of solid-state elctrncs such as CMOS prcss dvlpmnt & prcss intgrtn of slcn strctrs incldng slcn micromchng. Knldg of solid state devcs & crct dsgn & smltn. Abl to modl to implmnt base undrstndng of physcs into cmptr prgrm. Abl to use VLSI dsgn CAD tls. Job site: Santa Clara, CA. Ph.D. EE. Entry Level. Salary: $55,000/yr. 40hrs/wk. Clip ad & submit w/ resume to Job #NOF 391, P.O. Box 9560, Sacramento, CA 95823-0560 no later than February 1, 1992.

Senior Process Engineer: Process definition, process integration and module definition for new production technologies including electrical characterization of semiconductor materials and devices. University level training, research background or experience in the following: Thin film deposition and characterization; Electrical and physical properties of semiconductor materials; IC Fabrication technology; Metal diffusion barriers on semiconductor substrates; Aluminum via filling and planarization used in VLSI multi-level interconnect technologies. Ph.D/equiv/Physics/Electrical Engineering. $4,370/mo. Job Location: Hillsboro, OR. Clip this ad and send with resume to Employment Division, Job No. 5550205, 875 Union St., N.E., Rm. 201, Salem, OR 97311, by January 30, 1992.

Northwest electronics company has a position for a Senior Software Engineer. The successful applicant will conduct research in and act as consultant to product divisions in the area of Digital Signal Processing (DSP); improve performance of existing products, suggest new products. Develop algorithms and write software to apply DSP Digital TV and Spectrum Analysis. Requires use of Multirate DSP, Adaptive DSP and Communication Theory. Help business groups develop, then test and evaluate hardware for implementing DSP algorithms. Minimum requirements: PhD Electrical Engineering (Research and coursework in DSP, especially Multi-Rate DSP and Adaptive Filtering). Understands TV Systems and Video DSP. Exposure to use of Spectrum Analysis and DVSP Algorithms. Experience in writing software for "C" in Unix and for DSP microprocessors. Demonstrated ability in communication by international conference presentations in signal and image processing field. Hours are 8 to 5 Monday through Friday. Base salary: $55,000. Applicants must have legal authority to permanently work in the United States. Send resumes to: Job Order # 5550204, 875 Union St. NE, Salem, OR 97311. An Equal Opportunity Employer.

Product Line Manager. Established instrumentation mfgr. seeking Power Engineer with 10+ years experience in electric utility power relaying, metering, or analysis at the Transmission/Distribution level. Manager is responsible for marketing/engineering/customer liaison and product definition to meet the needs of utility/industrial power providers. Travel is required. Engineering degree (BSEE preferred) and superior communications skills essential. Position is on company's strategic R&D team, requiring significant individual contributions to entire product life-cycle. Position available at company headquarters in Rochester, New York, with attractive benefits and salary commensurate with experience. Send confidential resume to Rochester Instrument Systems, 255 N. Union St., Rochester, N.Y. 14605. EOE M/F H/V.

President/CEO. U.S. company seeks President/CEO to direct all operations of the company, including assisting U.S. companies in developing business in Israel and Europe with a major emphasis on Israeli business development in the area of energy and petrochemicals. Individual must possess knowledge of business development in energy and high technology pertaining to the petroleum, energy and petrochemical industries. Duties will include identifying sources of venture capital and supervising the professional team in the United States and abroad in financing, negotiating, contracts and obtaining licenses from foreign governments, when applicable. Applicants must have a bachelor's degree in chemical or petroleum engineering and a master's degree in business administration with a concentration in marketing and/or finance. Must have four years experience in contract negotiations with foreign governments and six years executive experience with a corporation having an annual

gross income of $500 million. Send resume to Board of Directors (VPI), P.O. Box 1748, Silver Spring, MD 20915-1748.

System Engineer, Design, develop, & implement system diagnostics & fault isolation programs on a Computer Network Voice Switching and Control System to detect & improve fault isolation capability based on voice & data communication standards, and CCITT X.21 and X.25 protocols. This job also includes integration computer network, and voice & data communication technologies to design & develop system test procedures, & execute these procedures. C, UNIX/SHELL, Intel 80286 and Motorola 68000 Assembly languages are used on a UNIX based development environment. Requires Master's in Electrical Engineering and 1 year direct experience in the job described. However, in lieu of 1 year direct experience performing above job duties, willing to consider a candidate with 1 yr. exp. in computer network, voice/data communication protocol development which includes CCITT X.21 and X.25 protocols; Plus graduate research project in UNIX operating system with C and SHELL languages, and graduate courses (one course each) in Information Modulation and Coding, and Communication Filters. Salary $39,000/yr, 40hrs/wk, 8am—5pm, no o.t., M-F. Must have proof of legal authority to work permanently in the U.S. Send resume to Illinois Department of Employment Security, 401 South State Street-3 South, Chicago, IL 60605. Att: Len Boksa, Ref.#V-IL 3336-B. No Calls. An Employer Paid Ad.

Chief Engineer. Innovative, young medical company seeks a seasoned professional to oversee development of a system that combines imaging technology with surgical robotics. The position requires strong project management skills; familiarity with FDA regulations for documentation and validation; ability to integrate complex systems, establish rigorous development standards, and interact with customers. Knowledge of UNIX and C++ helpful. Send resume to VP RD&E, P.O. Box 340669, Sacramento, CA 95834-0669.

Postdoctoral Fellow (Bio-Electrical Engineer) Resp. for carrying out rsrch in biomedical engrg incl. ultrasonic imaging, biomedical product development, surgical telepresence and parallel computing. Duties incl. development of transducers & analog & digital electronic hardware for applic. in advanced ultrasonic imaging systems, development of control software, software interface for automatic control and remote manipulation of surgical instrumentation. Reqs. Ph.D. in Electronic/Electrical Engrg plus 1 yr. exp. in job offered or in postdoc. rsrch in ultrasonic imaging. Also reqs. doctoral rsrch conc. & record of publications or other significant contributions in the field of ultrasonic imaging; also reqs. proven rsrch backgr. in: development of ultrasonic transducers & 1-D & 2-D arrays (simulation & manuf.); analog & digital circuit design & PC-based digital control; rsrch backgr. & knowl. of theoretical & applied signal processing/image processing (incl. 1-D 2-D FFT, z-transforms, spatial filtering); knowl. of C & assembly programming. Salary: $33,000/yr. Job & intrvw site: Menlo Park, CA. Send this ad & a resume to Job #SK2380, P.O. Box 9560, Sacramento, CA 95823-0560 not later than January 14, 1992. Must have legal right to work.

Device Engineer, Senior. Design & develop new generation non-volatile FLASH memory devices; conduct device & process characterization; investigate techniques for improved device performance; conduct test pattern design, test generation & silicon characterization of submicron MOS device structures and non-volatile memory arrays. Ph.D. in Electrical Engineering. Academic project/research background in development, fabrication, characterization, modeling and analysis of semiconductor processes and devices, including physical and electrical characterization, solid state and semiconductor physics, IC fabrication processes including diffusion, oxidation, rapid thermal processing, metallization, evaporation and photolithography, device testing and characterization techniques; academic coursework in VLSI fabrication. $4,500/mo.; 40 hrs./wk. Place of employment and interview: Santa Clara, CA. If offered employment, must show legal right to work. Send this ad and your resume to: Job No. CR 4480, P.O. Box 9560, Sacramento, CA 95823-0560 not later than January 30, 1992. The company is an equal opportunity employer and fully supports affirmative action practices.

Engineer, Process. Design, execute & analyze experiments for VLSI manufacturing, characterization & optimization; conduct electrical device characterization & failure analysis; perform device design & debugging; analyze effects of process & equipment changes on monitors, including CDs, film thickness & particle counts; evaluate & select VLSI technology options. M.S. in Solid State Physics, or Solid State Science and Technology, or Electrical Engineering. Academic project/research background in VLSI fabrication, including thin film deposition & characterization, analysis & characterization techniques including x-ray diffraction & spectroscopy, reflection high-energy electron diffraction and thin film thickness measurement, C & statistical analysis tool RS/1; academic coursework in materials characterization, thin solid films, electronic materials & solid state physics and devices. $3,200/mo.; 40 hrs./wk. Place of employment and interview: Aloha, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order Number 5550201, 875 Union Street, N.E., Salem, OR 97311, not later than January 30, 1992. The company is an equal opportunity employer and fully supports affirmative action practices.

VLSI Engineer: Participation in design and implementation of integrated circuits for several international standards in the area of electronic imaging and the coded representations of picture and audio information; implementation of the Joint Photographic Experts' Group (JPEG) standard for still pictures; direct involvement in the Motion Pictures Experts' Group (MPEG) standards decoder chip implementation for full motion video; responsibility for decoder designs; implementation of such standards requiring familiarity with high frequency signal processing VLSI circuits; set up and operate a state-of-the-art design facility, involving integration of hardware from several vendors, and coordinate the process of acquisition, storage, processing and display of signals via VLSI design. Applicants should possess: 6 years college; Master's degree in Electrical Engineering. Graduate-level research must include at least one (1) course in each of the following subjects: 1) Digital Image Processing; 2) Integrated System Design; 3) Digital Signal Processing; 4) Data Communication. Graduate-level research work must include multi-dimensional bilinear recursive filters for signal processing with applications to speech processing, image modeling and coding; implementation in VLSI of fast DSP algorithms; and data communication techniques for error correction and coded waveforms. 40 hrs./wk.; 9:00 a.m.- 5:00 p.m.; $36,540.00/year. Must have proof of legal authority to work permanently in the U.S. Send resumes to Illinois Department of Employment Security, 401 South State Street, 3 South, Chicago, Illinois 60605. Attn.: Richard Weston. #V-IL-4623-W. No Calls. An Employer Paid Ad.

Integration/Device Engineer—High-tech company located in the Northwest is looking for an Integration/Device Engineer. Requires M.S. in Electrical Engineering and 1 year of experience in CMOS processing. Responsible for the development of semiconductor processing steps needed to fabricate 0.5 micron double metal technology on six inch wafers. Responsibilities include device characterization, process integration and reliability tests. Will analyze electric characteristics using HP 4142 and will analyze C-V characteristics using HP 4280. Will conduct electromigration and stressmigration tests for aluminum alloys or different passivation layers. Will use SEM to obtain optical information. 40 hours a week, plus overtime as needed. Salary: $34,000 -$36,000/yr. Mail resume by February 3, 1992 to: Employment Security Department, Job #293554, Olympia, Washington 98504.

Engineering Analyst—Perf. R&D in dig. commun. area; dev. efficient Monte Carlo simulation; design mod./demod. schemes using statistical commun. & estimation theory; design system & anal. capacity for dig. commun. in fading by applying info. theory, error-correcting coding, multiple access, cellular system & diversity reception; dev. spread spectrum/CDMA with PN sequence acquisition/tracking. Knowl. of UNIX-based workstation. Rqmts: Ph.D. in Electrical Engr. and 1 yrs. exper. and Engr. Analyst or Research Asst. in Elec. Engr. field. M-F, 40 hr./wk., 8:30-5:00; Sal: $55,000/yr. Mail resume & copy of ad to MD DEED, 1100 N. Eutaw St., Rm 212, Balto., MD 21201; JO #9049187; Job Location: Clarksburg, MD.

Senior System Engineer: R&D of synthetic aperture real time imaging systems for medical applications. Design & fabrication PVDF sensors & sensor arrays. High level synthetic aperture imaging system design & simulation. Ph.D. in elec & comp eng. req'd. Must have expertise in: beam forming & synthetic aperture imaging techniques; Fourier optics & optical hologram technique; wave interference pattern analysis & application in imaging & signal processing; fiber-optic data transmission systems & optical WDM techniques. Hands-on exp. in piezoelectric polymer transducer array design, simulation & fabrication; acoustic material characterization, data acquisition & processing; microfabrication incl. clean room operation & material characterization using SEM; analogue electronic circuit design & simulation using PSPICE. Programming ability using C/C++. Familiar w/CADKEY. 40+ hrs/wk. $55K/yr. Jobsite int: Irvine, CA. Send resume to: IEEE Spectrum, Box 1-2, 345 East 47th Street, New York, NY 10017.

Engineer, Senior Technology. Resp. for rsrch & design to estab. reliability standards for present & new technologies for semiconductor devices. Duties incl. developing models for use in circuit simulation to predict device reliability with respect to electromigration, hot electron degradation & oxide breakdown; determining design rules to ensure reliability; developing test structures & performing characterization to evaluate reliability. Reqs. Ph.D. in Electr. Engrg. Also reqs. doctoral rsrch emphasis on silicon semiconductor devices, device characterization & reliability; doctoral rsrch should incl. practical development of process technology & its impact on reliability; knowl. of: device physics & reliability physics; testing & modeling of electromigration; circuit simulation; test structure design; statistical experimental design & analysis; semiconductor characterization techniques & equipment. Salary: $55,000/yr. Job & intvw site: San Jose, CA. Send this ad & a resume to Job #EG14278, P.O. Box 9560, Sacramento, CA 95823-0560 not later than January 31, 1991. Must have legal right to work.

Positions Wanted

Ph.D. in Electrical Engineering, age 39, German nationality, currently working in Germany, is seeking a new career opportunity, preferably in a leading position in R&D, either in University, governmental lab. or industry. Experience: (1) 7 years university research in electromag. compatibility, EM theory, numerical methods for antennas and scattering, microwave scattering measurements; (2) 6½ years aerospace industry R&D in microwave instrumentations for remote sensing satellites, microwave and millimeterwave microstrip antennas and planar passive circuits, radar system simulation software. Languages: fluent in English, German, French, and Japanese. Place preference: Europe. Please send responses to IEEE Spectrum, Box No. 1-1, 345 East 47th Street, New York, NY 10017 USA.

Innovative Russian Scientist—Electromagnetism. Levitation. Plasmodynamics. Arch. Induction Furnaces. 100 publications. Thirty-five years research and teaching top Moscow institutions. Presently unemployed Israeli citizen seeks any academic or research position: Prof. Moses Zarudi, D.Sc. Histadrut 4k-4 Petach-Tikva (972-3) 931-2592.

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Circle No. 24

IEEE Conference on

WIRELESS LAN IMPLEMENTATION

Sponsored by the IEEE Computer Society

September 17-18, 1992
Dayton, Ohio

CALL FOR PAPERS

Conference Scope

In today's business world, reorganization and associated equipment moves are the norm. With budget cutbacks, there is even less money available for costly re-cabling projects. This expense may be avoided through the use of emerging wireless LAN technologies. This conference focuses on wireless LAN technologies, such as spread spectrum radio, infrared and carrier current. Original papers are encouraged describing research and development of wireless products as well as implementation techniques using existing technologies.

Committee

General Chair:
Jim Geier
WPAFB, OH
513/255-6224

Program Chair:
Barbara Moore
Frontier Eng., Inc.
Dayton, OH
513/256-9464

Finance Chair:
Elaine Townsend
TRW
Dayton, OH
513/255-3542

TOPICS

- Case Studies
- Implementation
- Impact on Future of Networking
- Integrating Wireless/Wired LANs
- Human Factors
- Standards Development
- Wireless Products
- Economic Benefits
- Wireless Transmission Techniques
- Environmental Impact

Features

Keynote Speakers
Displays/Demonstrations
Technology Overview
Implementation Models

Abstract Submission

For author's kit contact:
Frontier Engineering, Inc.
5100 Springfield Pike
Suite 401
Dayton, OH 45431
513/256-9464
Fax: 513/256-9057

Key Dates

Abstracts Due 4/1/92
Acceptance Notification 4/10/92
Papers Due 6/11/92

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The College of Engineering and Applied Sciences (CEAS) invites applications for the position of Director of the newly created Aerospace Research Center in the College.

Qualifications:

An applicant is expected to have qualifications consistent with a full-time appointment in the College of Engineering and Applied Sciences at the rank of Professor. A history of significant research experience is required in one or more areas, including Aerodynamics, Propulsion, Flight Mechanics, Guidance and Control, Avionics, Structures, Materials, Robotics, and Automation, all as applied to the broad area of aerospace engineering. Evidence of an ability to generate external research support and to develop strong industrial relations is also necessary.

Scope:

The successful applicant will be expected to create an environment within which cross-disciplinary research is fostered, regardless of the applicant's own specialty. This cross-disciplinary research should bring together not only the different departments within CEAS but should include the technical staffs of our local industry.

Some funding for the Center is available from the State, as part of the Engineering Excellence plan. But several local aerospace firms have made significant financial commitments towards the establishment of the Center as well. Finally, federal funding for several research projects has also been obtained. The successful applicant will be expected to build on and to expand this support base.

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Engineering departments, schools struggle to survive

Dwindling enrollments, soaring expenses, and an economic recession are root causes of struggles for survival by engineering departments in many U.S. colleges and universities. The board of trustees of Pratt University, Brooklyn, N.Y., for example, is considering closing its engineering school entirely unless the faculty comes up with a working plan to save it. Union College in Schenectady, N.Y., and Hofstra University, Manhattan College, and the Polytechnic University, all in the New York City area, have been seriously affected. And Yale University, New Haven, Conn., and Syracuse University, Syracuse, N.Y., are among the general private institutions asking whether their engineering schools in their present forms are relevant to their overall mission [THE INSTITUTE, Jan./Feb., p. 1].

IEEE cuts deficit

The IEEE's operations for the year ending Dec. 31, 1991, will finish ahead of budget by more than US $500 000. That was the message conveyed by Treasurer Theodore W. Hissey Jr. to the Board of Directors at its final 1991 meeting in Orlando, Fla., in November. This result represents a sharp turnaround from 1990's budgeted deficit of $2.5 million. And 1992's general fund operating budget is slated to show a surplus of more than $1 million in a budget of $52 million [THE INSTITUTE, Jan./Feb., p. 1].

IEEE names new Fellows

The IEEE has named 244 new Fellows for outstanding contributions to the electrical and electronics engineering profession [THE INSTITUTE, Jan./Feb., p. 4].

British score in controlled fusion

Scientists at Culham Laboratories in Oxfordshire, England, have reported the first controlled fusion reaction to combine tritium with deuterium. The reaction on Nov. 9 produced 1.5–2 MW of power in a 2-second pulse but the crucial break-even point—when fusion power produced equals the power used to heat the plasma, the plasma attains the correct temperature and density, and fusion lasts long enough—was not reached [THE INSTITUTE, Jan./Feb., p. 1].

Business turning up?

Various trade groups and prognosticators in the U.S. government believe that 1992 will be better than 1991, in which a persistent U.S. recession due to sluggish sales caused substantial employee cutbacks in the electronics industry. *Electronic Business Forecast Newsletter*, Newton, Mass., using data from the U.S. Department of Commerce and trade groups, predicts an upswing this year, with new orders from U.S. factories for electronics in general up 7.4 percent in dollar terms from a year ago. But forebodings are almost as numerous as rosy predictions. The American Electronics Association, Washington, D.C., reports, for example, that the world market share for U.S.-owned electronics firms dropped from 64.5 percent in 1985 to 50.5 percent in 1990. For electronics firms on U.S. soil, the decline was even worse during the same period—from 52 to 32.9 percent of the world market [THE INSTITUTE, Jan./Feb., p. 1].

Coming
in Spectrum

WARC-92. The World Administrative Radio Conference of 1992 must somehow find room in the electromagnetic spectrum for new services like mobile-radio satellites, digital pocket phones, digital audio broadcasting, and high-definition TV.

BOUNDARY SCAN TESTING. This technique for testing chips through their pins has long been applied to custom ICs. But as loaded circuit boards have become ever more cumbersome to test, the industry has decided to standardize the procedure.

OPTICAL SWITCHING. In development in laboratories around the world are optical switching devices, which obviate the need to convert light into electricity for switching and back into light for transmission.

SIGNAL STABILITY IN COLOR. A new technique enables digital scopes to reveal as much as analog scopes about signal stability. It's the use of color to indicate the frequencies with which waveform points occur over time.

BATS' EARS IMITATED. At Brown University, Providence, R.I., an algorithm based on the bat's echo location abilities has been implemented in a very large-scale IC.

ENGINEER ENTREPRENEUR. One star of the Gulf War was a tiny, portable receiver that "plugged" a soldier into the U.S. Global Positioning Satellite System. It was only one of the many brainchildren of Charles R. Trimble, an entrepreneurial engineer.

GEOTHERMAL PROS AND CONS. Several places, notably Hawaii and the Philippines on the Pacific's volcanically active rim, have ambitious plans to tap their geothermal resources. But the plans are opposed by environmental and native groups.

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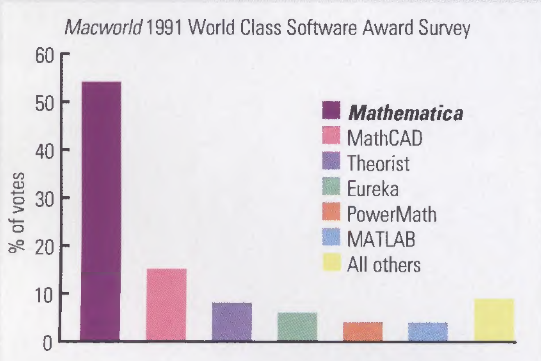

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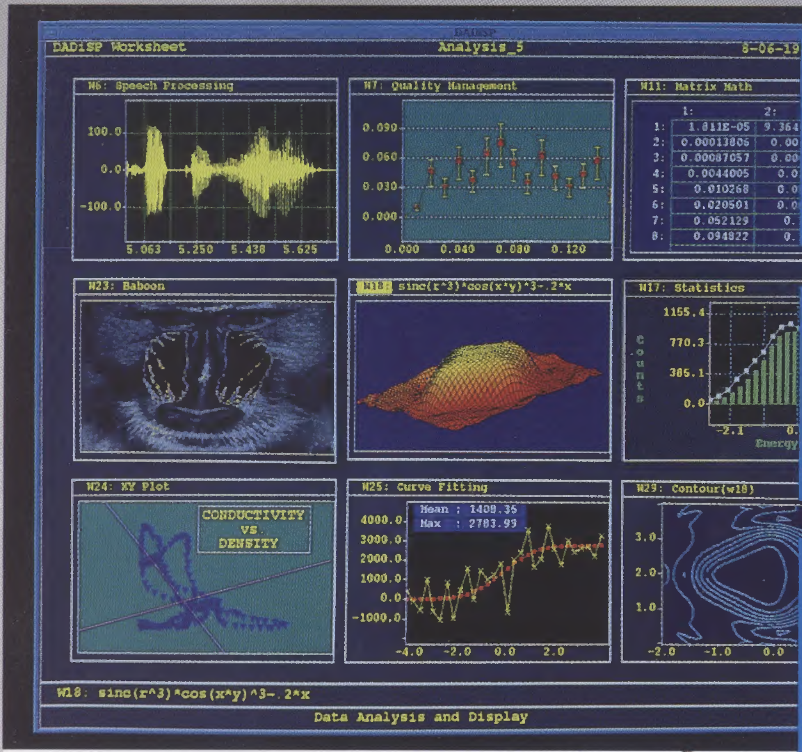

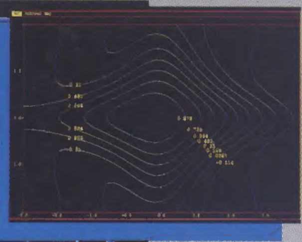

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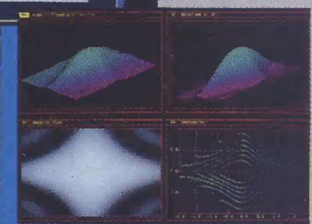

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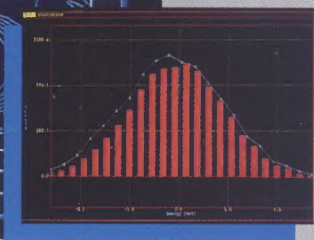

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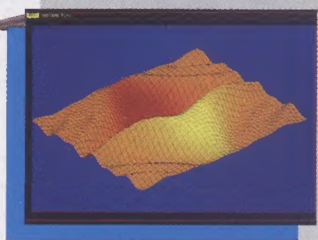

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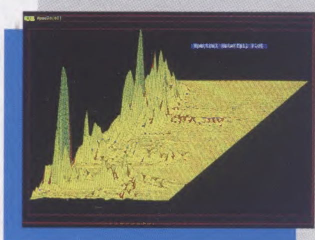

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